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Final Report

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Spacecraft Utensil/ Hand Cleansing Fixture

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FINAL REPORT

SPACECRAFT UTENSIL/ HAND CLEANSING FIXTURE

December 1975

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FOREWORD

This document presents the results of work performed by the Martin Marietta Corporation's Denver Division for the National Aeronautics and Space Administration, Johnson Space Center. This final report was prepared as partial fulfillment of Contract NAS9-14671, Spacecraft Utensil/Hand Cleansing Fixture. The NASA Technical Monitor was Mr. John B. Westover, Systems Support Branch.

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ABBREVIATIONS AND ACRONYMS

AC	Alternate Current
Atm	Atmosphere
BT	Brushing Teeth
BTU	British Thermal Unit
BW	Body Wash
^{o}C	Degree Celsius
CFM	Cubic feet per minute
cm	Centimeter
CMS	Cubic Meters per second
Cp	Specific Heat
cu	Cubic
db	Dry bulb
DC	Direct Current
EC/LSS	Environmental Control/Life Support System
^{o}F	Degree Fahrenheit
FPM	Feet per minute
fps	Feet per second
ft	Feet
G	grain
g	gram
gal	gallon
gpm	gallon per minute
HA	Hair Wetting
Hg	Mercury
hr	hour
HW	Handwashing
Hz	Hertz
in	inch
Js	Joules
^{o}K	Degree Kelvin
kg	Kilogram
KW	Kilowatt
lb	pound
l	liter

LGS	Liquid-Gas Separator
M	Mass
m	Meter
min	minute
ml	milliliter
mm	millimeter
MPS	meter per second
N	Newton
N_2	Nitrogen
O_2	Oxygen
P	pressure
PID	Positive Isolation Disconnect
ppm	parts per million
psi	pounds per square inch
psia	pounds per square inch absolute
psig	pounds per square inch guage
s, sec	second
SCFM	Standard cubic feet per minute
SCMS	Standard cubic meters per second
SH	Shaving
Sq.	Square
T	Temperature
ut	utensil cleansing
V	Volume
VAC	Volts-Alternate Current
VDC	Volts-Direct Current
W	Weight
wb	wet bulb
#	Pound
Ø	Phase

I. INTRODUCTION

Space flights in the past have indicated a need for a more conventional and natural means for washing hands or utensils. A personal hygiene device of this nature will be even more desirable when Space Shuttle payloads include biological testing. Previous development cleansing methods fell into one of the following groups:

- o Washcloth cleansing
- o Waste water collector and wash unit

The "washcloth cleansing" method consisted of cloth wetting, wiping, and then squeezing water from the washcloth. Problems with this method were:

- o Complete cleanser removal cannot be accomplished since rinsing action is not available.
- o Water removal from washcloth is difficult and time consuming.
- o Possibility of escapement of cleansing agent into the habitability area.
- o Logistic requirements are excessive.

The "waste water collector and wash unit" method can be improved upon and was the purpose of the efforts undertaken. The objective of this contract was to develop a system concept for an inflight utensil/hand cleansing fixture which included the following features:

- o Capability for efficient cleansing and rinsing of utensils or hands.
- o Provision for general waste fluid disposal.

The design concept for the utensil/hand cleansing fixture provides for the capability of functioning for a 30 day Shuttle mission containing seven occupants/users. The long range goal for this development is to provide a functioning system capable of operating for extended missions of at least 120 days. The utensil/hand cleansing fixture is designed as a self-contained unit that can be installed in the standard water interface requirements. Service to the unit is a single source of unheated potable water and water discharged from the unit is into a single return waste connection. In addition, the design includes provisions for the intake and discharge of purge air and the discharge of evolved gases. Both the air and the gases are filtered or processed in the utensil/hand cleansing assembly before releasing them into the habitability area. The unit is designed to operate effectively on nominal 28 VDC and 115 VAC, 400 Hz power.

The output of this final report is to identify the tasks involved in the final design concept selection and to define the system design and performance requirements.

II. TECHNICAL APPROACH

A. TASK ONE - SELECTION OF CONCEPT

The objective of Task One was to formulate conceptual designs that would result in minimum impact to a Shuttle payload. This involved the preparation of a functional task analysis and subsequent development of a preliminary design document, performing a technology survey, evaluating candidate hardware, developing potential system concepts and selecting one or more candidate systems. The output of this task was a tradeoff analysis report, system schematics, packaging concepts, and a soft mockup of the selected cleansing fixture.

B. TASK TWO - FEASIBILITY TESTING

The objective of Task Two was to conduct preliminary laboratory tests to determine the feasibility of a potential concept. This involved developing test requirements, configuring and performing the feasibility testing, and evaluating the test data. The output of this task was to quantitatively establish the cleansing fixture's criteria ranges that would be utilized in the preparation of the Requirements Definition Document.

C. TASK THREE - REQUIREMENTS DEFINITION DEVELOPMENT

The objective of Task Three was to formulate a Requirements Definition Document that would define the cleansing fixture's system design and performance requirements. This was accomplished by defining the selected system based on the outputs of Task One and Task Two and specifying performance and design requirements. The output of this task was a Requirements Definition Document in accordance with the requirements of the DRD MA-516T.

D. TASK FOUR - DOCUMENTATION AND PRESENTATIONS

The objective of Task Four was to provide the necessary conference requirements, data management requirements, and documentation requirements. All items identified and described by the Data Requirements List (DRL) No. T-1097 were prepared and submitted. The data items were prepared in accordance with the Data Requirements Description (DRD) referenced on the DRL for each line of data. All reports and documentation (except engineering drawings) generated under this contract were expressed in SI (metric) units with conventional units given in parentheses. In addition to these formal documentation submittals, telephone calls on a weekly basis were made to the NASA technical monitor at his convenience to inform him of current progress, evaluations, and results.

In addition to satisfying the formal documentation requirements, a presentation/conference meeting was held at NASA-JSC after completion of the Selection of Concept Task (three months after contract go-ahead) and after completion of the Development of the Requirements Definition Document (six months after contract go-ahead).

III. HARDWARE/SUBSYSTEMS TRADEOFFS

The objective of this tradeoff analysis was to formulate system and subsystem concepts for the cleansing fixture and to evaluate the concepts to determine their impact on the spacecraft. Factors that were considered in the selection included power requirements, volume, weight, functional reliability, maintainability, and impact on the EC/LSS system. The output of this tradeoff analysis is a recommended system concept that meets the design requirements and is then further developed in the feasibility testing phase of the program.

A. REQUIREMENTS

The cleansing fixture's purpose is to provide efficient capability for cleansing and rinsing of utensils or hands and to provide for general waste fluid disposal. The design of the unit must be formulated based upon technical, design and performance requirements. The tradeoff analysis conducted for both the subsystems and systems utilized the following requirements.

1. Technical Requirements

a. Washing - The utensil/hand cleansing fixture shall be designed such that the user is able to get direct contact of water and cleanser on his hands without loss of the water into the habitability area. In addition, the fixture shall be configured so as to allow visual inspection of the cleaning operation by the user. The unit shall have both an automatic and a manual mode of operation. It shall have the capability of varying the water temperature and shall have appropriate temperature controls accessible to the user.

b. Rinsing - The design shall include the capability for rinsing without loss of water into the habitability area. The rinse water temperature shall also be adjustable with controls accessible to the user.

c. Automatic Operation - Automatic operation shall be provided in the design along with a manual override. The automatic mode shall be such as to allow predetermined setting of controls so that a complete wash/rinse/drying or purge cycle is provided following the activation of a start switch.

d. Air Purge - The design shall include the capability to remove the used wash/rinse water from the fixture. This shall be accomplished by purging the unit with air after each use. The used air shall be filtered and/or processed as required to remove contaminants or objectionable odors before it is returned into the habitability area.

e. Gas-Liquid Separation - The design shall include the capability to separate gas from liquid in a weightless environment. The gas shall be vented through a filter or processor to remove contaminants or objectionable odors before it is returned into the habitability area. The liquid will be pumped/routed to a container suitable for waste water storage in a null gravity. Ultimate disposal of the waste water shall not be a consideration of this effort.

f. Water Limiting Devices - The design shall include the capability to limit the usage rate of water for a given wash cycle. The optimum and minimum acceptable rates will be established during the feasibility testing of the selected concept.

g. Design Life - The design life for the utensil/hand cleansing fixture shall as a minimum be capable of functioning for a 2.592×10^6 second (30-day) Shuttle mission.

h. Microbiological Control - Provisions for the control of microorganisms within the fixture to include periodic cleaning and maintenance shall be incorporated in the design.

i. Configuration Requirement - The utensil/hand cleansing fixture shall be designed as a self-contained unit that can be installed in the standard Shuttle Payload configurations with a minimum of hardware changes and water interface requirements.

2. Design Requirements

a. Cleansing Fixture System

1) The fixture shall have the capability to operate in either zero or one-gravity environment.

2) The fixture shall be designed to accommodate a 5th/ to 95th/percentile male/female crew size based on anthropometric dimensions of the USAF population projected to 1980.

3) The fixture shall be designed utilizing MIL-STD-1472B as a human engineering and man/machine guideline.

4) The fixture shall include self-contained restraints for feet, hands, and items which must be temporarily restrained.

b. Structure

1) Structural load requirements - Design loading shall be 3 g's maximum for 1800 seconds (30 minutes) to satisfy launch and re-entry requirements and 12 g's maximum for crash loading.

2) Structural members shall be of aluminum material to meet the structural loading requirements.

3) The structures design shall contain stowage provisions for support items to the fixture.

3. Performance Requirements

a. Crew Sizing - The system sizing shall be based upon 7 occupants/users for a 2.592×10^6 second (30-day) Shuttle mission. The long range goal for this development would be to provide a functioning system capable of operating for extended missions of at least 10.368×10^6 seconds (120 days) with 7 occupants/users.

b. System Tasks - The cleansing fixture system design shall accommodate the following crew functions:

- Washing hands and face
- Sponge bathing
- Shaving and cleaning razor

o Brushing teeth
o Washing or wetting of hair
o Oral hygiene such as mouth rinse
o Handwashing of small parts or individual items of clothing
o Waste fluid disposal
o Cleansing utensils

c. Interface Requirements

1) Cabin Environment

a) Cabin Atmosphere:

Total Pressure:	O_2/N_2 1.013×10^5 N/m^2 $\pm$ .173 N/m^2 (760 mmHg $\pm$ 13 mmHg)
O_2 Partial Pressure:	2.2×10^5 N/m^2 $\pm$ .173 N/m^2 (165 mmHg $\pm$ 13 mmHg)
CO_2 Partial Pressure:	.067 N/m^2 (5 mmHg) Nominal .101 N/m^2 (7.6 mmHg) Maximum

b) Humidity: Controlled within 25% to 70% and is not adjustable.

c) Temperature: 291°K to 301°K (64°F to 81°F) db

d) Allowable Heat Rejection: Maximum nominal 1000W, peak 3000W

2) Power Interfaces

Spacelab Nominal 28 VDC
115/200 volt, 400 Hz

3) Water Interfaces

a) Water Supply - single source of unheated potable water between 286.3°K and 322.5°K (55°F and 120°F) temperature.

b) Water Discharge - Single return waste connection.

4) Air Interfaces

a) Air Intake - Cabin atmosphere as defined in a).

b) Discharge Air - Filtered and/or processed as required to remove contaminants or objectionable odors.

5) Structure Interface - The cleansing unit shall be designed to be installed into a Spacelab standard rack as defined in Para. 4.1.1.2 of the Spacelab Payload Accommodation Handbook, dated October, 1974, ESTEC Reference No. SLP 2104.

6) Assumed Equivalent Weight Penalties

Penalty Type	Equivalent Ratio
Heat added directly into cabin which must be removed with cabin cooling circuit	.198 kg/Js (.128 lbs/BTU/hr)
Continuous DC Power	268 kg/Kw (591 lbs/KW)
Continuous AC Power	322 kg/Kw (710 lbs/KW)

7) Pressurant Gas Interface

Gas: Nitrogen

Pressure: 413.4×10^3 N/m^2 (60 psig) maximum

B. ENCLOSURE CONFIGURATION

1. Functional Requirement - The fixture design shall be designed such that the user is able to get direct contact of water and cleanser on the crewmen's hands without loss of the water into the habitability area. In addition, the fixture shall be configured so as to allow visual inspection of the cleaning operation by the user. Provisions for control of microorganisms within the fixture shall be incorporated in the design. Also, the fixture shall provide for utensil washing and waste fluid disposal.

2. Technical Design Requirement

- o Operate in either zero or one-gravity environment
- o Accommodate a 5th to 95th percentile male/female
- o MIL-STD-1472B anthropometric requirements for 95th percentile male:

Hand Length: 20.67 cm (8.14 inches)

Elbow-Finger Tip Length: 51.82 cm (20.4 inches)

Hand Breadth: 9.73 cm (3.83 inches)

Arm to Elbow Access Hole Diameter: 11.43 cm (4.5 inches)

- From mockups and testing, natural angle formed between man's arms (from his elbow to the fingers) when simulating hand washing is approximately 110°.

3. Enclosure Configuration Concepts

a. Hemisphere Dome with Shallow Cone Base - This enclosure consists of a hemispherical dome that is attached to the shallow cone base by either a hinge so that the dome can be lifted up or a pivot so that top can pivot to one side. This will permit placing utensils in the fixture or the disposing of waste fluids. Hand access holes are 12.7 cm (5 inches) in diameter and located near base of dome. The included angle formed by the centerlines of the hand holes normal to the enclosure axis is 110 degrees. The diameter of the dome and mating cone base is 30.48 cm (12 inches) which provides adequate sizing to allow for the hands and wrists to be inserted for washing. Hand access holes are covered by elastic material (slit to allow hand insertion) to seal against water spillage. Soap and water interface with the enclosure will be in a location that does not interfere with normal handwashing. Top center of dome would be such a location, since washing of the hands should take place at the maximum diameter of the enclosure (dome/base interface) to take advantage of the bulk volume in that section.

b. Truncated Cone Lid with Shallow Cone Base - This enclosure consists of a truncated cone lid that is attached to the shallow cone base by either a hinge so the dome can be lifted up or a pivot so that the top can pivot. If desired, both motions can be incorporated by use of a ball-joint assembly or a universal joint. These lid movements are required for placement of utensils within the enclosure and the dumping of waste fluids. Hand access holes are 12.7 cm (5 inches) in diameter and located near the base of the lid. These holes are covered by slitted elastic material to seal against water spillage. The angle formed by the center-lines of hand holes normal to the enclosure axis is 110 degrees. The diameter at the lid/base interface is 30.48 cm (12 inches) which is the region where the hand-washing operation takes place. The soap and water to enclosure interface would most likely be positioned at the top portion of the lid to avoid interference with the crewmen's hands during washing.

c. Flat Surfaced Enclosure - This enclosure incorporates a transparent lid that has a flat top and angled front where the hand holes are located. The diameter of the hand holes are a minimum of 15.24 cm (6 inches) since the crewmen's arms are not perpendicular to the enclosure surface containing the handholds during a normal handwashing operation. The lid is hinged along the back edge to allow access inside the enclosure for utensil washing. These items may be too awkward to insert through the hand access openings. This concept also incorporates flexible slitted arm seals over the hand holes. The enclosure has flat sides with a total width of 43.18 cm (17 inches), depth of 30.48 cm (12 inches), and a wash volume height of 30.48 cm (12 inches). The base of the enclosure tapers down and back for water - air collection. Wash water is provided by four nozzles located in the upper back corners and lower front corners.

d. Forward Air-Water Entry, Aft Air-Water Exit - This concept positions the water injectors on the front panel where the hand access holes are located. The top surface contains a window for viewing and is angled down approximately 30 degrees to be normal to crewmen's line-of-sight. The unit is box shaped with rounded corners. The back surface contains the collection port for air and waste water.

e. Cone Shaped Enclosure - This enclosure is a truncated cone shaped unit inverted with the large end at top. The enclosure height is 35.6 cm (14 inches) with the large end being 30.5 cm (12 inches) in diameter and the small end 3.2 cm (1.25 inches) in diameter. The 12.7 cm (5 inch) diameter hand holes are centered 12.7 cm (5 inches) from the top and are in-line with each other. Flexible arm seals are attached to the hand openings to prevent spillage. The floor to enclosure height is approximately chest high to maintain adequate visual inspection of the handwashing operation. Soap and water dispensing can be positioned at a convenient location on either the walls or top surface. This enclosure is unique in that the air blower can be either up or downstream from the enclosure.

f. Flexible Bag/Wringer Mechanism - This novel concept utilizes a flexible flat bag with a water inlet at one end and the waste water outlet at the other end. Slits are provided along the edges to allow the insertion of the crewmen's hands. Opposing rollers provide the means of transferring the waste water from the bag to the storage tank by squeezing the bag as it travels from one end to the other.

g. Standup Cylinder - This concept utilizes a straight cylinder 30.8 cm (12 inches) in diameter by 45.72 cm (18 inches) tall for the washing enclosure. An access door is provided that opens at the cylinder diameter with a height equal to that of the cylinder. This provides for the placement of articles in the enclosure or disposing of waste fluids. With the enclosure positioned 91.44 cm (36 inches) to 137.16 cm (54 inches) above the floor level and with the large opening in the enclosure provided by the hinged door, a crewman is capable of inserting his head into the enclosure for hair washing. Hand access holes are also located on the hinged door with the same general configuration as in the other concepts, that is, 12.7 cm (5.00 inch) diameter openings with an angle of 110° between them, and covered by elastic material with slits to allow hand insertion. The base of the straight cylinder mates with a cone section in the component module that funnels waste water to a vacuum pickup area. Soap acquisition can be accomplished through an integrated pressurized supply system or brought into the enclosure as a separate entity. Water supply can be through a flex line with a hand held nozzle attached to the interior surface of the enclosure.

4. Matrix Comparisons

TABLE III-1 Characteristic Comparison

Characteristic \ Concept	Hemisphere Dome with Shallow Cone Base	Truncated Cone Lid with Shallow Cone Base	Flat Surfaced Enclosure	Forward Air-Water Entry, Aft Air-Water Exit	Cone Shaped Enclosure	Flexible Bag/ Wringer Mechanism	Stand-Up Cyl-inder
Visibility	1	1	1	1	2	4	1
Volume Utilization	1	2	4	3	3	1	1
Water Utilization	1	1	4	4	1	2	2
Ease of Unit Cleaning	1	2	3	2	3	4	1
Arm Positioning	1	1	2	2	3	2	1
Efficiency of Water Collection	1	1	3	3	1	2	1
Rinsing Thoroughness	2	2	1	1	2	3	1
Reliability (Degree of Complexity)	1	1	1	1	1	2	1
Compliance with Utensil Washing and Waste Fluid Disposing Requirement	1	1	1	4	4	4	1
TOTALS	10	12	20	21	20	24	10

CODE: 1 - Best, 2 - Second Best, Etc.

4. Matrix Comparisons (Cont'd)

TABLE III-2 Operational Comparison

Parameter \ Concept	Hemisphere Dome with Shallow Cone Base	Truncated Cone Lid with Shallow Cone Base	Flat Surfaced Enclosure	Forward Air-Water Entry, Aft Air-Water Exit	Cone Shaped Enclosure	Flexible Bag/ Wringer Mechanism	Stand-up Cyl-inder
Interior Surface Area	2480 cm^2 (2.67 ft^2)	3456 cm^2 (3.72 ft^2)	8222 cm^2 (8.85 ft^2)	7432 cm^2 (8.0 ft^2)	2954 cm^2 (3.18 ft^2)	2230 cm^2 (2.4 ft^2)	4376 cm^2 (4.71 ft^2)
Interior Volume	11100 cm^3 (0.392 ft^3)	20332 cm^3 (0.718 ft^3)	42475 cm^3 (1.50 ft^3)	42475 cm^3 (1.50 ft^3)	11553 cm^3 (0.408 ft^3)	2832 cm^3 (.1 ft^3)	33414 cm^3 (1.18 ft^3)
Area/Volume Ratio	6.74	5.18	5.9	5.34	7.8	24.0	3.99
Required Air Flow	30 CFM	30 CFM	30 CFM	5500 CFM	30 CFM	None	45 CFM

5. <u>Enclosure Configuration Concept</u> - Two concepts were selected for further evaluation. The first concept selected for the hand washing enclosure is the hemisphere dome with shallow cone base, due to the following:

a. High visual inspection of handwashing operation.

b. Volume has been optimized (total volume is small, but adequate for comfortable washing).

c. All water used is directed towards hands and, therefore, minimum amount of water is used (negligible overspray).

d. Since interior area is small and surface is smooth, cleaning is easily accomplished.

e. Design provides for natural arm positioning.

f. Water collection is performed efficiently with cone base and with water flow in direction of sump.

g. Design provides access to interior of enclosure for utensil washing and disposing of waste fluid.

The second concept selected is the standup cylinder configuration, due to the following:

a. High visual inspection of handwashing operation.

b. Elimination of sharp corners provides for ease of cleaning.

c. Design provides for natural arm positioning.

d. Water collection is performed efficiently with cone base.

e. Design provides for versatility in dispo ing waste fluids, washing utensils, and provides a facility for crewmen's hair washing.

C. WATER LIMITING DEVICES

1. <u>Functional Requirement</u> - The fixture design shall include the capability to limit the usage rate of water for a given wash cycle.

2. Technical Design Requirements

Crewmen: 7

Usage frequency: 10 per day/crewman

Assume maximum total quantity of water required per wash: 227 grams (.5 lbs)

3. Water Limiting Device Concepts

a. Flow Nozzle with Isolating Valve - Technique that utilizes a low flow rate nozzle that distributes water efficiently and is controlled by crewman action (foot control, knee control, forearm control, or hand control) through an isolating valve only when water is required.

b. Skylab Handwasher Dispenser - Technique in which crewman inserts hands within enclosure and depresses water dispenser push button with hand.

c. Preloaded Water Tank with Isolation Valve - This technique involves preloading a measured volume of water into a bladder tank. The bladder tank is then pressurized and the water could be expelled upon demand through an isolating valve. This technique could utilize any of the activation concepts and flow nozzles described in one above. The design characteristics concerning water usage would be comparable with the other techniques.

4. Matrix Comparisons

TABLE III-3 Characteristic Comparisons

TECHNIQUE CHARACTERISTIC	FLOW NOZZLE/ VALVE	SKYLAB DISPENSER	PRELOADED BLADDER TANK
Water Usage - kg (#/Day)	.44 (58.3)	.47 (61.6)	.44 (58.3)
Hand Free Capability	Yes	No	Yes
Automatic Capability	Adaptable	Modification to Existing Hdwre	Adaptable
Pre-Wash Activity	None	None	Load Tank
Enclosure and System Interface Volume	Smallest	Largest Within	Largest Within System
Operating Pressure N/m^2 (psig)	137.8×10^3 (20)	241.2×10^3 (35)	$137.8 \times 10^3 - 275.7 \times 10^3$ (20-30)
Maximum Water Usage	Unlimited	Unlimited	Restricted to Tank Volume
Flow Rate $m^3/s \times 10^{-5}$ (gpm)	1.89 (.30)	2.02 (.32)	1.89 (.30)
Flow Pattern	25^o Cone	Solid Stream	25^o Cone
Theoretical Coverage at 20.3 cm (8 Inches) from Orifice in cm (Inches)	8.9 (3.5)	Stream Diameter	8.9 (3.5)
Cost	Least	Most	Intermediate
Maintainability	Best	Intermediate	Least
Reliability	Best	Best	Worst
Training Requirements	Easy	Easy	Worst
Overall Performance	Best	Intermediate	Worst
Skylab Experience	Yes	Yes	No

5. <u>Design Approach Selection</u> - The flow nozzle with isolating valve is selected for the water limiting device due to the following:

a. Allows the hands to be free for washing each other or utensils at all times.

b. Permits the most efficient distribution of water from a spray angle and impact velocity standpoint in relation to a 95 percentile man's hand.

c. Proven water limiting distribution concept based upon Skylab shower nozzle experience.

d. Least impact on enclosure volume.

e. Easily adaptable to an automatic system for washing either the hands or utensils.

f. Least cost impact.

D. WATER COLLECTION SUBSYSTEM

1. <u>Functional Requirements</u> - The cleansing fixture shall include the capability to remove the used wash/rinse water by purging the unit with air after each use.

2. <u>Technical Design Requirements</u>

- Crewmen: 7
- Usage Time: 82 seconds including cleanup
- Usage Frequency: 10 per day/crewman
- Maximum Basin Area to Wash Hands: 30.5 cm (12 in.) dia
- Water Movement in Zero-g Attached to Surface: 10.1 m/sec (33 fps)

  NOTE: 12.19 m/sec (40 fps) will be utilized since 10.1 m/sec (33 fps) is a marginal value and a more realistic value is desired.

- Assumed Blower Efficiency: 60%
- Assume for Air Flows of $<$ .305 m/sec (1 fps), no heat is required
- Cabin Environment: 294.3°K (70°F) db
- Assume LGS is Vortex type requiring 1.42×10^{-3} CMS (3 CFM) recirculating air to prevent liquid carryover

3. <u>Water Collection Subsystem Concepts</u>

a. Air Drag Technique - Utilization of air for complete removal of water from basin by flowing 12.19 m/sec (40 fps) uniformly throughout basic cross-sectional area.

b. Low Air Purge - Technique that requires removal of water manually by hand or scraper aids toward fixture outlet drain. The waste is carried to the liquid gas separator by air flowing at 12.19 m/sec (40 fps) in the drain tubing to move the liquid in zero-g.

c. Vacuum Pickup - Technique that utilizes a flexible hose that can be maneuvered within the fixture enclosure similar to a vacuum pickup. The air flowing in the hose is sized for 21.4 m/sec (70 fps) so that in a one-"g" operation, water can be picked up when the hose is in a verticle position (negative 1-"g"). A minimum suction pressure of .254 meter (10 inches) of water is required in addition to the 21.4 m/sec (70 fps) to pick up water in a negative 1-"g".

d. Absorption by Sponge/Cloth - Technique in which water is absorbed in a material such as a sponge/cloth after a fixture usage. The sponge/cloth is then washed and dried in a combination washer/dryer Martin Marietta report, MCR-72-109, Clothes and Dishwasher and Dryer Concept Study, defines several concepts for a washer/dryer.

e. Evaporation - Technique in which dry heated air flows through enclosure and absorbs the moisture. The air must then be reconditioned back to the cabin environment level either by refrigeration or by either absorption or an absorption technique.

4. Matrix Comparisons:

TABLE III-4 Power Comparison

H_2O COLLECTION TECHNIQUE	AIR CMS (CFM)	BLOWER POWER	JOULES/DAY (WATT-HRS/DAY) HEATER POWER	TOTAL	EST. TIME (SEC)
Air Drag	.89 (1884)	2.11×10^7 (5858)	1.65×10^8 (45625)	1.86×10^8 (51485)	45
Low Air Purge	8.5×10^3 (18)	1.21×10^5 (33.6)		1.21×10^5 (33.6)	38
Vacuum Pickup	1.32×10^{-2} (28)	4.7×10^5 (130.6)		4.7×10^5 (130.6)	38
*Sponge/Cloth Absorb-tion				1.12×10^6 (312*)	38
**Evaporation 960 sec (16 min)	4.72×10^{-2} (100)	1.12×10^6 (311)	1.97×10^7 (5473)	309×10^6 (5784**)	960

*Washer/Dryer Penalty = 1.12×10^6 joules/day (312 watts-hrs/day)

**Cooling Coil Penalty = 5584 joules/sec/day (18,612 BTU/hr-day)

TABLE III-5 Component Comparison

TECHNIQUE / REQUIRED COMPONENTS	AIR DRAG	LOW AIR PURGE	VACUUM PICKUP	ABSORPTION	EVAPORATION
Liquid-Gas Separator	X	X	X		X
Blower	X	X	X		X
Air Contaminent Filter	X	X	X		X
Water Pump	X	X	X		X
Waste Bladder Tank	X	X	X		X
Air Heater	X				X
Clothes Washer/Dryer				X	
Cooling Coil					X

TABLE III-6 Characteristic Comparison

CHARACTERISTIC \ TECHNIQUE	AIR DRAG	LOW AIR PURGE	VACUUM PICKUP	ABSORPTION	EVAPORATION
Number of Components	3	1	1	5	4
Cost	3	1	2	4	5
Maintainability	3	1	2	4	5
Reliability	3	1	2	4	5
Volume	3	1	1	4	5
Weight	3	1	1	4	5
Power	4	1	2	3	5
Training Requirements	1	3	2	3	4
Performance	1	3	2	5	4
Safety	1	1	1	2	2
Cleanup Time	4	1	1	1	5
Spacecraft Penalties	3	1	2	4	5

CODE: 1 - best, 2 - second best, etc.

5. Design Approach Selection - The low air purge and vacuum pickup techniques are selected to be carried into the system definition phase. This selection is based upon the fact that both techniques meet the functional requirement, have the lowest power requirements, and the least number of components which directly effects the cost, maintainability, reliability, volume, weight and penalties characteristics.

E. LIQUID-GAS SEPARATORS

1. Functional Requirements - The cleansing fixture shall include the capability to separate gas from waste water in a weightless environment. The liquid will be pumped/routed to a container suitable for waste water storage in a null gravity.

2. Technical Design Requirements

- Support the water collection subsystem
- .0085-.0132 CMS (18-28 CFM) air
- Maximum per usage of 3 grams of soap, low sudsing
- 1.9×10^{-5} to 6.31×10^{-5} MPS (.3 to 1 gpm) .019 kg/sec to .063 kg/sec (2.5 #/min to 8.3 #/min) per usage
- 98-100% efficiency required for free droplets of liquid in processed air stream
- Compatible with wash waste contaminated with a mixture of hair, dirt, soap and water. Also must be compatible with a variety of chemical waste products
- Usage frequency, 7 crewmen, 10 usages per day at 900 seconds (15 minute) intervals

3. Liquid-Gas Separator Concepts

a. Centrifugal Separators - There are two concepts for a centrifugal liquid-gas separator design, a paddle wheel concept and a rotating bowl concept. A two-phase air-liquid mixture is drawn into a stationary housing and due to the centrifugal force of a rotating paddle wheel or a rotating torus shaped bowl, the water droplets are accelerated in an outward radial direction. The centrifugal forces continue to cause the water to travel along the housing or rotating drum until it reaches a gutter at maximum drum radius. A pitot tube converts the kinetic energy of the water into a pressure head. The design of a centrifugal separator can incorporate a pumping head to the water and act as a fan to move the air. The power required to operate a paddle wheel separator is substantially higher than for a rotating bowl because of fluid friction. The dynamic seals and bearings fail due to contaminants and liquid loading after short periods of operation. Also, the paddle wheel pumping capability is a function of liquid level, requiring a booster pump to empty the separator. A filter screen must be included over the pitot tube to prevent clogging. Skylab experience has shown that the pitot tube in the moving liquid creates turbulence and subsequently foaming in contaminated liquids such as soapy waste or urine. In addition, particulate and gummy contaminants tend to build up in small passages and reduce pumping capability. In order to reduce the foaming problem, the drum speed is reduced which takes a longer time to pump out liquid wastes (i.e., liquid waste cannot be removed at the same rate generated by the user).

b. Vortex Separators - The basic operation of vortex separation involves tangential injection of a two-phase mixture, in this case gas/liquid, into a cylinder, causing a vortex motion. The vortex motion causes a centrifugal force field which causes the heavier phase (liquid) to move to the outer wall of the cylinder. The gas, or lighter phase, remains in the center of the cylinder and is drawn out from the center at one end of the cylinder. The heavier liquid follows the vortex flow on the outer wall and is moved to the opposite end of the cylinder by a decreasing static pressure gradient. This pressure gradient is increased by placing a conical portion of the liquid outlet end. The conical portion causes an increasing vortex velocity gradient toward that outlet due to the decreasing area. Since the increase in velocity comes from available static pressure, and the decreasing static pressure gradient toward the liquid outlet end is pronounced.

The total (static and dynamic) pressure within the separator is highest at the two-phase inlet, remains high at the walls, and is low in the center along the separator longitudinal axis. The lowest pressure is at the apex of the cone at the liquid outlet. The decreasing static pressure gradient at the walls can be made strong enough to push liquid out against a one gravity field (-1g).

Gas flow in a vortex separator is three-dimensional and very complex. At every point within the separator, gas velocity can be resolved into three components: tangential, axial and radial. The tangential component is predominant throughout the entire separator except in the highly turbulent region in the center. The axial component is directed toward the liquid outlet at the walls, and toward the gas outlet in the center. This phenomenon directs separator design toward ensuring that all liquid is centrifuged to the walls before it reaches the apex of the liquid outlet cone, or the axial component will carry the liquid out the gas outlet. The radial velocity component is directed toward the center throughout most of the separator, thus requiring that the design results in sufficient centrifugal force on the liquid at the walls to override the radial velocity component toward the center. Manipulation of these characteristics through proper design of the separator components ensures efficient operation within a given system.

Vortex separators have no moving parts, do not depend on surfaces subject to plugging or contamination, and do not require expendables. These factors enhance reliability and maintainability. Vortex separators of the type required for this effort have a pressure drop from the two-phase inlet to the gas outlet of approximately 5.08 to 10.16 cm (2 to 4 inches) of water. A separate blower is required to move the air through the system and a water pump is required to pump the waste water to a holding tank. A small percentage of air is necessary to be recycled back through the separator to prevent water carry-over into the air stream.

c. Elbow Separator - The elbow separator is similar to the vortex separator in that a centrifugal field is set up as the air flows around the elbow, causing the water droplets to impinge on the outside wall.

The water flows through the porous wall due to capillarity and the reduced pressure behind the wall. Wicking is utilized to minimize air carry-over. Separation efficiency increases as the length of the porous wall is increased and as the radius of the bend is decreased. A separate air blower and fluid pump are required to move the gas and fluid through the system. The primary disadvantage to a wick is that the contamination in the fluid tends to clog and frequent maintenance would be required.

d. Hydrophilic/Hydrophobic Separators - In the operation of a Hydrophilic/Hydrophobic Separator, a mixture of liquid and gas entering the unit is divided into separate liquid and gas streams leaving the unit. Single-surface and two-surface separators, each having a number of possible configurations, can perform this separation. In a single-surface unit, a membrane is provided which will pass either gas or liquid, depending on whether it is hydrophobic or hydrophilic. The remaining constituent of the inlet mixture passes over the membrane and out of the separator as a pure stream. In a two-surface separator, both the liquid and gas constituents in the feed must respectively pass through hydrophilic and hydrophobic surfaces before leaving the separator.

These concepts can meet the performance criteria only under closely controlled, ideal laboratory conditions. The hydrophilic screens are extremely sensitive to a solids clogging problem due to contamination in the liquid, becoming inoperative in a few hours with ordinary distilled water, and in a few minutes with ordinary tap water. The hydrophobic screens are extremely sensitive to the surface tension of the liquid and become wetted immediately on contact with water and soap solutions. This is true with all the currently acceptable cleansing agents. These concepts must utilize a separate blower and pump to move the gas and fluids.

e. Hydrophilic Separator - The hydrophilic separator design is based on a porous screen used as the hydrophilic surface. As the primary element in the separation process, a screen of Dutch twill weave 304L stainless steel with an absolute micron rating of 15 to 18 (250 x 1370 mesh) is utilized. When wetted, the screen becomes hydrophilic, thus creating a stable gas/liquid interface. A hydrophilic screen will pass liquid and reject gas if the screen is entirely wetted and the pressure differential across it does not exceed a figure characteristic of the individual screen (the "bubble point"). If the pressure differential exceeds the bubble point, the screen will pass gas along with the liquid.

The total system consists of a cone assembly, air reduction valve, venturi, blower, and supply and storage tanks. The liquid outlet line is connected to the storage tank with its exist at the height of the top of the separator cone.

With the blower in operation, air flow from the two-phase inlet through the separator assembly, valve, venturi, and blower is established. When water is introduced at the two-phase inlet, it becomes entrained in the moving air and is transported through four flow fingers, where the two-phase mixture emerges with a velocity tangential to the base-cone side. Thus the flow is directed at the hydrophilic screen where water droplets impinge on and are conducted through the screen. As the screen reflects the flow, a circular flow pattern around the cone is formed. Since the air exit is at the top of the cone, a conical spiral flow up the cone is also established. As the flow proceeds us the cone, impinging water is removed by the screen so the exit air is free of water. As the air passes through the cone apex outlet and the venturi, a negative pressure is created at the throat of the venturi, providing suction at the liquid storage tank. This negative pressure is also felt on the liquid side of the screen and, with essentially atmospheric pressure on the two-phase side of the screen, provides the ΔP necessary for liquid flow.

This separator is sensitive to contamination in the fluid as the screen becomes readily clogged with solids. In addition, the screen hydrophilic characteristic changes when a soap mixture comes into contact. The screen demonstrates a hydrophobic characteristic.

f. Porous Plate Separators - The porous plate separator is composed of parallel metal frame with sintered porous metal plates fastened to frames. The air stream enters the top of the unit and is deflected by a series of baffle plates in a manner to throw the aerosols to the sintered plate during each reversal of direction of the air stream.

The low pressure on the liquid side of the sintered plates is created by a solenoid driven, oscillating, two stage, bellows pump. This pump is to remove the water migrating through the plates, at a varying flow rate, while maintaining a constant suction pressure.

The unit is designed such that the sintered plates must be thoroughly saturated with water before initial start-up. If the sintered metal is pre-saturated and all air is also removed from the water passages, capillary action will prevent air breakthrough in the pores of the sintered metal. The filled water passages will maintain this saturated condition by capillary action. These plates have an average pore size of two microns, a porosity of twenty-seven percent, an air breakthrough of 8.42×10^4 N/m^2 (twelve and two tenths psi) differential when saturated and pass 18.6×10^4 milliliters per square meter per sec (5.3×10^{-4} gallons of water per square inch per minute) at a differential pressure of 6.9×10^3 N/m^2 (one psi).

Another version of the porous plate separator utilizes impingement chevrons. These chevrons are constructed of 50.8 x 50.8 (20 x 20) stainless steel screen. The screen is cut on a 45° angle so that almost all strands terminated at the sintered plates. This is to insure that any aerosol impinging on the screen would flow to the sintered plate in an unbroken pattern when subjected to the velocity of the air stream. Each chevron is composed of 5 layers of screen with air gaps between these layers. Four chevrons in series are placed between each pair of adjacent sintered plates.

These separators are easily clogged due to contaminents in the fluid. A separate blower and pump are required to move the liquid and gas streams.

4) Matrix Comparison

TABLE III-7 Comparison of Separator Characteristics

CHARACTERISTIC \ SEPARATOR CONCEPT	CENTRIFUGAL		VORTEX	ELBOW/ WICK	HYDROPHILIC/ HYDROPHOBIC		POROUS PLATE	
	SSP PROGRAM	SKYLAB PROGRAM			COMB	PHILIC	BAFFLE	CHEVRON
Air Flow CMS x 10^{-4} (CFM)	9.44 (15)	70.8 (2)	944 (200)	520 (110)	67 (14)	47.2 (10)	47.2 (100)	1420 (300)
Liquid Flow kg/sec (#/min)	.2 (5.3)	.045 (5.94)	.063 (8.34)	.04 (5.3)	.025 (3.33)	.063 (8.34)	.0003 (.036)	.0003 (.036)
Efficiency (%)	98	98	99		99	99	60	81.5
Compatible with Contaminants	Yes	Yes	Yes	No	No	No	No	No
Maintainability	3	2	1	4	5	5	6	6
Development Status	Lab	Skylab	KC-135	Skylab	Lab	Lab	Lab	Lab
Air Flow Pressure Drop cm H_2O (in. H_2O)			10.16 (4)		325 (128)	10.16 (4)	1.27 (.5)	2.8 (1.1)
Blower Pump Incorp.	Yes	Yes	No	No	No	No	No	No
Liquid Discharge = Intake	Yes	No	Yes	Yes	No	No	No	No

5. <u>Design Approach Selection</u> - The rotating bowl centrifugal separator and the vortex separator concepts are selected to be carried into the system definition phase. This selection is based upon their development status. The vortex is selected due to having no moving parts, not depending on surfaces subject to plugging or contamination, and not requiring expendables. The rotating bowl centrifugal concept is attractive due to having the water pump and blower being an integral part of the concept. In addition, this unit was flown on the Skylab. All other concepts are rejected primarily due to relative dependance on surfaces subject to plugging and contamination. This lowers the reliability and increases the maintenance activity. The paddle wheel centrifugal was rejected due to a higher power requirement, seal and bearing failures, and a requirement for a separate pump to empty the bowl.

The primary tradeoff in the system definition phase between the vortex and centrifugal separators will focus on the power and weight requirements for a separator versus the power and weight required for the operation of the centrifugal separator which incorporates the blower and pumping action. Other areas of investigation will include the pumping time of the centrifugal separator to determine if it can pump at a rate to meet the crewman usage requirements and maintainability requirements.

F. CLEANSING FIXTURE CONCEPTS

The above subsystem concepts can be formulated in a number of combinations to make up a preliminary fixture system concept. Five such system concepts were formulated and are described in the following paragraphs:

1. Cleansing Fixture Concept Number One

a. System Description

<u>Cabinet and Enclosure</u> - The cabinet that houses the components is mounted in a standard Spacelab rack structure. The overall dimensions are 50.76 cm (22.52") wide by 67.44 cm (29.92") deep by 157.1 cm (69.7") high. The enclosure is a 27.05 cm (12") diameter polycarbonate hemispherical dome that is hinged and sealed to the cabinet.

The basin is a thirteen and a half centimeter (six inches) deep cone that reduces to 2.54 centimeter (one inch) diameter outlet at the apex. Two arm entrance holes with center lines located 110° apart permit entry of the hands. These openings are covered with an elastomer cover, slitted for hand and process air entrance. Interfacing with the enclosure is the water distribution nozzle, the soap dispensing nozzle and the disinfectant nozzles (3). The inside of the enclosure and basin contain smooth corners to prevent bacteria growth.

<u>Water Distribution Subsystem</u> - The Orbiter/Spacelab supplies potable water to the interface through a positive isolation disconnect (PID). This disconnect has poppet valves in each half that allows the cleansing fixture to be pressurized with water and mated to a pressurized potable water system thus preventing a separate purge and fill cycle onboard the spacecraft. Potable water fills the two and three tenths kilogram (five pound) holding tank and heated by a direct immersion heater to 320.4°K (117°F) in 7200 seconds (2.0 hours). A solenoid valve, actuated when a foot pedal is depressed, manually allows water to flow to the nozzle through an ion exchange resin bed for a specified time as desired by each crewman. The ion exchange resin bed prevents microbiological back contamination of the potable water system. The water distribution system contains an orifice to maintain the potable water system pressure at 1.38×10^5 N/m^2 (20 psig) at the nozzle interface. This allows a controlled flow rate through the nozzle at 1.58×10^{-5} CMS (.25 gpm).

<u>Soap and Disinfectant Distribution Subsystems</u> - Nitrogen gas is utilized as a pressurant to expel soap and disinfectant from their bladder tanks to the nozzles in the cleansing fixture enclosure. The nitrogen subsystem contains a pressure regulator and isolation valves so that the same nitrogen source can be utilized for the waste water bladder tank. The soap storage bladder tank contains sufficient liquid soap (6300 grams) for the entire mission. A foot operated switch activates a solenoid valve that controls soap flow from the bladder tank into the cleansing enclosure.

Water Collection Subsystem - The blower draws 5.64×10^{-3} CMS (12 cfm) of air through the 2.54 cm (1 inch) drain outlet (10.1 m/sec (33 fps) flow necessary to move water in zero-g). The air/water mixture exits the enclosure and enters a vortex liquid-gas separator (LGS). Waste water is collected in a sump in the LGS and return air (free of water droplets) is routed to the axial vane blower. A small quantity of air 14.16×10^{-4} CMS ($<$ 3 CFM) is drawn from the pressure side of the blower and injected into the LGS to prevent liquid carry-over into the air stream. The bulk of the air from the LGS outlet is passed through bacteria and charcoal filters for revitilization before being dumped into the cabin. Air is drawn into the cleansing enclosure around the cuffs which allows the hands to be placed inside. This prevents water from escaping to the cabin atmosphere.

Waste Water Subsystem - Liquid level sensors in the LGS sump provide an actuation signal to the water pump when the LGS sump becomes full. The gear pump operates for a fixed time period (electronically controlled) to empty the sump and prevent pumping air into the waste water system. The waste water flows through a maintainable filter which can be removed and cleaned periodically without having to evacuate the water from the system lines. Positive isolation disconnects are provided on both sides of the pump to allow its removal and replacement (or repair) inflight without draining the system. The waste water is stored in a bladder tank which can be evacuated periodically as water usage rates require. The water is dumped by closing the isolation valve just ahead of the soap storage tank and opening the valve at the waste water tank gas inlet. Nitrogen pressurizes the bladder and expels the water past the isolation valve (closed on the water pump side) to the waste water interface with the Orbiter/Spacelab.

Drying Technique - The low air flow utilized to conserve system power necessitates drying the hands with a towel.

b. Electrical Subsystem - This design requires two different power sources -- 28 VDC (maximum load 100 watts) and 115 VAC, 1Ø, 400 Hz (maximum load 18 watts). With the circuit breakers of both sources closed and the main power switch in the "on" position, the water heat is energized and requires 7200 seconds (2 hours) to raise the 2.27 kilograms (5 pounds) of water from 286°K (55°F) (minimum) to the design wash water temperature of 320.4°K (117°F). When the hot water heater is energized, an indicating light on the operator's panel illuminates. When the water has reached 320.4°K (117°F), another indicating light on the operator's panel illuminates to signify that the cleansing unit is ready to use.

For a normal handwash operation, the automatic mode will generally be used. For other special washing requirements the manual mode can be selected.

For the automatic mode, the sequence mode switch is turned to the "auto" position. At once, the 115 VAC blower starts and runs throughout the cycle and an indicating light on the operator's console illuminates. At the same time, the water solenoid is energized for 4 seconds to allow the user to pre-wet his hands. Then the soap solenoid is actuated for a 4-second interval to spray soap on the user's hands. During the next 20 seconds, the user washes his hands while the blower continues to operate. Next, the water solenoid is energized for 10 seconds to spray rinse water into the fixture. Next the user has 30 seconds to clean the fixture with his hands before drying with towels. The blower continues to operate for 20 seconds to purge the system and the automatic cycle is completed.

For the manual mode, the sequence mode switch is turned to the "manual" position. Regardless of the temperature of the water, the manual operation of the equipment can be accomplished by the proper switch position. The blower still operates at all times the sequence mode switch is on the manual position and the blower indicating light is illuminated. The water pump can be activated at any time and runs for the predetermined time of 11 seconds. This switch is a spring-return switch that always returns to the automatic position. The level sensor on the pump is energized in the manual mode. Water and soap are dispensed at will in the manual mode by use of the foot switches. Disinfectant can be sprayed in the wash basin by turning the disinfectant switch to the manual mode. The disinfectant must be turned "off" when enough has been sprayed into the bowl. The manual mode continues until the sequence mode switch is placed in the "off" position.

In either the automatic or manual mode, the water heater continues to function as an independent unit to maintain the water temperature at 320.4°K (117°F).

2. Cleansing Fixture Concept Number Two

a. System Description - The cabinet and enclosure is essentially the same as for Concept Number 1 with the exception of component/subsystems differences as follows:

1) The liquid soap dispensing system is replaced with bar soap.

2) The vortex liquid-gas separator is replaced with a centrifugal liquid-gas separator (LGS). Since the centrifugal LGS has an integral pump system, the water pump, maintainable filter and one PID are eliminated. In addition, the air injection line to the vortex LGS is not required.

3) Nitrogen system eliminates soap isolation valve.

b. Electrical Subsystem - This design is basically the same as Concept Number 1 except that a 28 VDC source for the centrifugal separator (has integral pump) is used instead of the 200 VAC pump that operates in conjunction with the liquid-gas separator. Since there is only one requirement for AC power (Blower) and it can be obtained at 115 VAC, that is substituted for the 200 VAC power shown in Concept 1.

Power requirements are 115 volts, 1 Ø, 400 Hz (16 watts) and 28 VDC (87 watts). The only operating difference in Concept 1 and Concept 2 is that the 28 VDC centrifugal separator in Concept 2 operates continuously throughout the cycle instead of from a timer.

3. Cleansing Fixture Concept Number Three

a. System Description - Concept 3 is essentially the same system as Concept 1 except as follows:

1) Enclosure Design - The enclosure for Concept 3 is a standup cylinder, 27.05 cm (12 inches) in diameter, with a hinged door containing two covered hand access holes. The door allows a crewman to insert his head for hair washing. The basin allows a vacuum pickup head to be mounted at the apex of the cone for a continuous water collection.

2) Water Distribution - The water distribution is the same as Concept 1 except that the distribution nozzle is a hand held, thumb operated on-off valve. The water on-off valve is a solenoid that has a manual override capability for manual operation. A flexible line allows maneuverability within the enclosure.

3) Water Collection System - The water collection system consists of a vacuum pickup collection head on the end of a flexible base. The blower is sized at 1.9×10^{-2} SCMS (40 SCFM) and 31.6 cm (14 inches) of static pressure.

b. <u>Electrical Subsystem</u> - Concept No. 3 is exactly the same as Concept No. 1 except that the excess water after the wash-operation is vacuumed from the bowl. This requires a larger blower which is 200 VAC. The power requirements are 200 VAC, 3Ø, 400 Hz (255 watts) and 28 VDC (57 watts).

4. <u>Cleansing Fixture Concept Number Four</u>

a. <u>System Description</u> - Concept 4 is the same as Concept 3 with the following exceptions:

1) The liquid soap dispensing system is replaced with bar soap.

2) The vortex LGS is replaced with a centrifugal LGS. Since the centrifugal LGS has an integral pump system, the water pump, maintainable filter and one PID are eliminated. In addition, the air injection line to the vortex LGS is not required.

3) Nitrogen system eliminates the soap isolation valve.

b. Electrical Subsystem - This design is exactly the same as Concept 2 except that the larger 200 VAC blower is provided for vacuum cleaning the fixture at the end of the rinse operation. The power requirements are 200 VAC, 3Ø, 400 Hz (195 watts) and 28 VDC (87 watts).

5. Cleansing Fixture Concept Number Five

a. System Description - Concept 5 is the same as Concept 1 except drying of the hands is accomplished by a hot air dry. This requires a larger blower capacity approximately 4.25×10^{-2} CMS (90 CFM) than for Concept 1. A bleed inlet allows 4.72×10^{-3} SCMS (10 SCFM) of relative dry cabin air to enter the system to maintain the recirculating air at a lower humidity than saturation. This allows the hands to be dried at a faster rate.

b. Electrical Subsystem - This design is similar to Concept Number 1. The blower wattage is larger than for Concept Number 1 but smaller than Concept 3. It must be capable of moving 4.25×10^{-2} CMS (90 CFM) of warm air into the bowl for hand drying, but it does not provide capability for vacuum cleaning of the bowl. Also, this concept incorporates a 28 VDC heater in the air duct to the bowl to heat the air temperature to 325.3°K (125°F) for hand drying. The power requirements are 200 VAC, 3Ø, 400 Hz (195 watts) and 28 VDC (1550 watts).

6. Matrix Comparison

TABLE III-8 IMPACT SUMMARY (PRELIMINARY TRADEOFF ANALYSIS)

CONCEPT / PARAMETER	1	2	3	4	5
Total water usage per day in kilograms/day (pounds/day) (7 crew persons @ 10 usages per day)	15.5 (34.1)	15.5 (34.1)	15.5 (34.1)	15.5 (34.1)	15.5 (34.1)
Blower static pressure - in cm of water (inches of water)	3.81 (1.5)	3.81 (1.5)	35.56 (14)	35.56 (14)	8.89 (3.5)
Blower volume flow rate in cubic meters per second x 10^{-3} (cubic feet per minute)	7.08 (15) ROTRON AXIMAX 1	7.08 (15) ROTRON AXIMAX 1	STAX-3-FC 18.9 (40) TRW 19A922	VAX-3-FC 18.9 (40) TRW 19A922	49.6 (105) TRW 19A751
Bleed air in cubic meters per second x 10^{-3} (cubic feet per minute)	7.08 (15)	7.08 (15)	18.9 (40)	18.9 (40)	4.72 (10)
Total blower power (in watts)	17	17	195	195	135
Blower on time per operation (in seconds)	88	88	88	88	118
Total blower on time per day in seconds (hours)	6156 (1.71)	6156 (1.71)	6156 (1.71)	6156 (1.71)	8244 (2.29)
Blower energy requirements in joules/day x 10^5 (watt-hrs/day)	1.05 (29.1)	1.05 (29.1)	12 (333.7)	12 (333.7)	11 (309.8)
Total heater power (in watts)	50	50	50	50	50

TABLE III-8 IMPACT SUMMARY (PRELIMINARY TRADEOFF ANALYSIS) (Cont'd)

CONCEPT / PARAMETER	1	2	3	4	5
Water heater energy requirements in joules/day x 10^6 (watt-hr/day)	2.27 (629.3)	2.27 (629.3)	2.27 (629.3)	2.27 (629.3)	2.27 (629.3)
Total water pump power (in watts)	60	--	60	--	60
Total centrifugal LGS power (in watts)	--	30	--	30	--
Water pump energy requirement in joules/day x 10^4 (watt-hr/day)	5.76 (16)	--	5.76 (16)	--	5.76 (16)
Centrifugal LGS energy requirement in joules/day x 10^5 (watt-hr/day)	--	2.81 (78.2)	--	2.81 (18.2)	--
Total pumping time per day in seconds (minutes)	980 (16.3)	9380 (156.3)	980 (16.3)	9380 (156.3)	980 (16.3)
Free moisture in cubic meters x 10^{-4} (cubic inches)	2.36 (14)	2.36 (14)	2.36 (14)	2.36 (14)	--
Towel latent penalty in joules/day x 10^5 (BTU/day)	5.4 (510)	5.4 (510)	5.4 (510	5.4 (510)	--
Total air heater power (in watts)	--	--	--	--	1500
Total usage time of air heater in seconds (minutes)	--	--	--	--	2100 (35)

TABLE III-8 IMPACT SUMMARY (PRELIMINARY TRADEOFF ANALYSIS) (Cont'd)

PARAMETER \ CONCEPT	1	2	3	4	5
Air heater energy requirements in joules/day x 10^6 (watt-hr/day)	--	--	--	--	3.15 (875)
Cabin air into cleansing fixture ^oK dB (^oF dB)	300.9 (81)	300.9 (81)	300.9 (81)	300.9 (81)	300.9 (81)
Humidity (in percent)	70	70	70	70	70
Air entering basin outlet in ^oK dB (^oF dB)	302.6 (85)	302.6 (85)	302.6 (85)	302.6 (85)	302.6 (85)
Air leaving blower from fixture in ^oK dB (^oF dB)	299.8 (79.9)	299.8 (79.9)	301.47 (82.9)	301.47 (82.9)	299.86 (80)
Maximum sensible load in joules/day x 10^5 (BTU/day)	7.51 (711.5)	7.51 (711.5)	233 (2203.2)	233 (2203.2)	7.21 (683.1)
Maximum latent load in joules/day x 10^5 (BTU/day)	1.73 (164)	1.73 (164)	4.62 (437.1)	4.62 (437.1)	1.56 (147.9)

7. Cleansing Fixture Concept Selection - Cleansing fixture concept number one is selected as the optimum based upon comparative tradeoff analysis. This concept utilizes a low air purge and requires the crewman to assist in cleanup after usage. This concept has the least impact on the spacecraft systems and incorporates proven spacecraft subsystems.

The automatic mode of operation for the fixture is possible and has been incorporated in the concept, however, the efficiency of utilizing the fixture in this mode is questionable. The first detriment to automatic mode of operation is the length of time required to accomplish a task. For each step function, the timing sequence must be set for the maximum time so that all crewmen could accomplish their task completely. This requires the maximum power and impact on the spacecraft. If individual time sequences were programmed into the electrical circuitry for each subtask (i.e., rinsing), the operation of the fixture would be complicated for the crewman as well as having more hardware adding to weight, power and reliability.

IV. TASK TWO - FEASIBILITY TESTING

A. TASK OBJECTIVE

The objective of Task Two was to conduct preliminary laboratory tests to determine the feasibility of a potential concept. This involved developing test requirements, configuring and performing the feasibility testing, and evaluating the test data. Feasibility testing was performed to establish design criteria to be considered for future design parameters of the utensil/hand cleansing fixture.

B. TEST SET-UP

1. Test Fixture - A schematic of the test fixture is shown in Figure IV-1. Two hand holes with coverings are provided at the front of the enclosure. Testing results from a mockup indicated that the natural angle formed between a man's arms (from his elbow to the fingers) when simulating handwashing is 1.92 radians (110^{o}). The hand holes are placed so that this angle is obtained. Figures IV-2 and IV-3 show the test fixture set-up. Water was obtained from the laboratory faucet. A globe valve set the pressure of the water delivered to the fixture and a pressure gage monitored this value. When the water foot switch was activated, the water solenoid valve would open thus allowing water flow. Soap was stored in a calibrated burette and was delivered by gravity pressure to the soap nozzle when the soap solenoid valve would open by activation of the soap foot switch. A .007 CMS (15.58 CFM) air flow was provided by a blower to aid movement of water from within the enclosure down to the Liquid-Gas Separator. At this point, the air portion of the fluid-air mixture is returned to the lab ambient and the fluid was collected in a calibrated beaker.

During the testing, several minor changes to the fixture set-up were recognized, either due to system leakage of water or trying to minimize free water standing in the system. Also, changes were made to the fixture to prepare it for water balance test. The changes are summarized as follows:

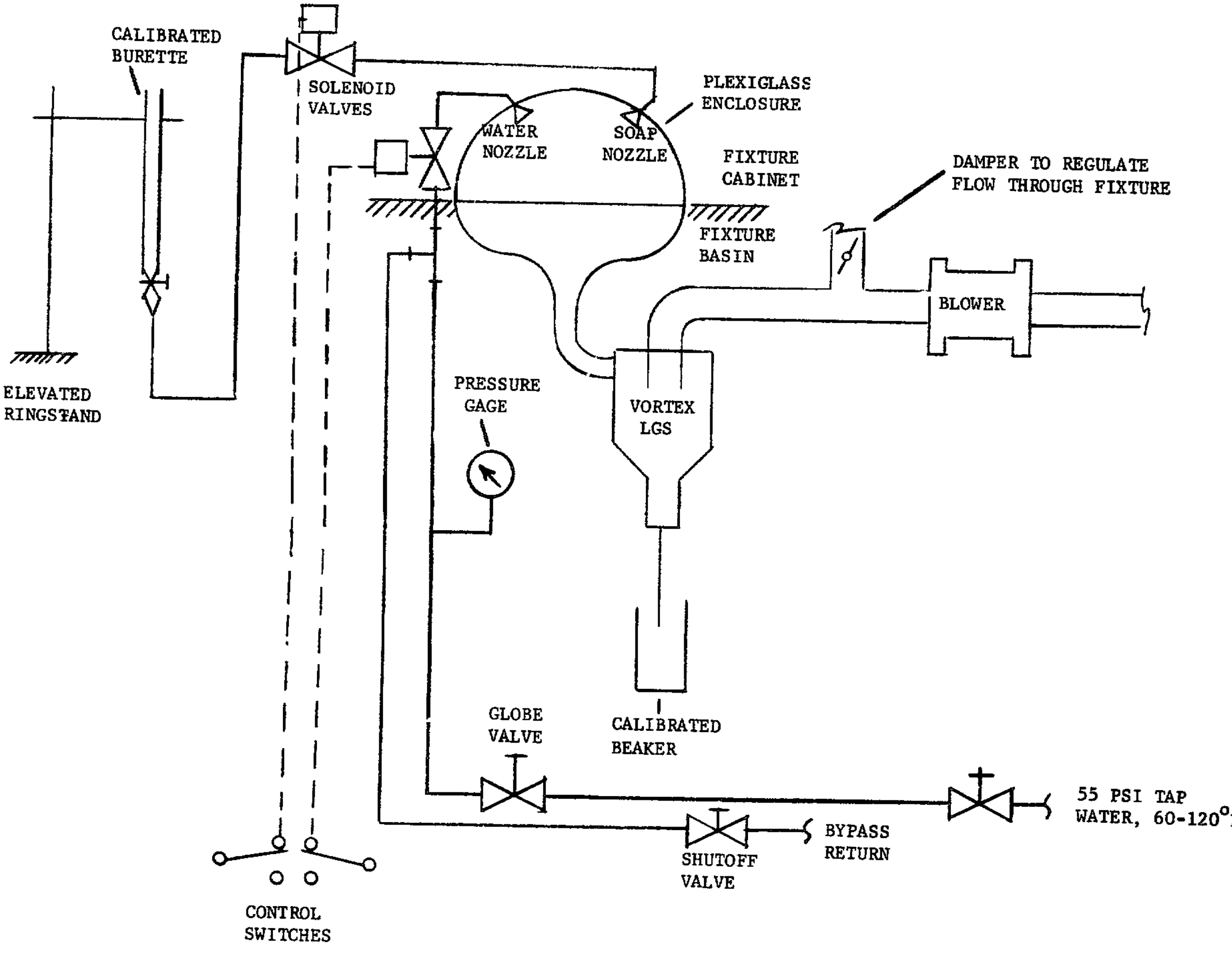

FIGURE IV-1 FEASIBILITY TEST SCHEMATIC

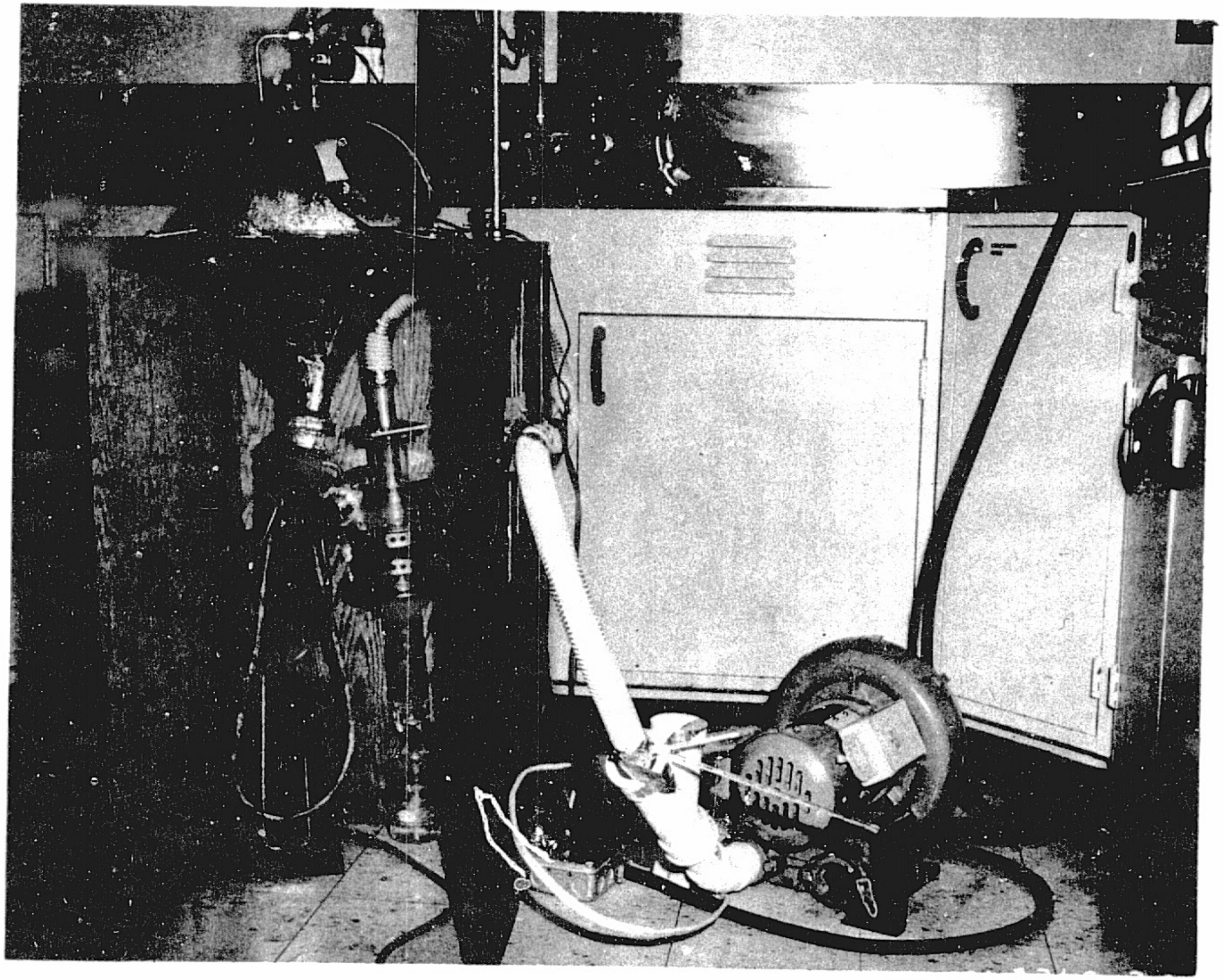

FIGURE IV-2 FRONT VIEW OF UTENSIL/HAND CLEANSING TEST FIXTURE

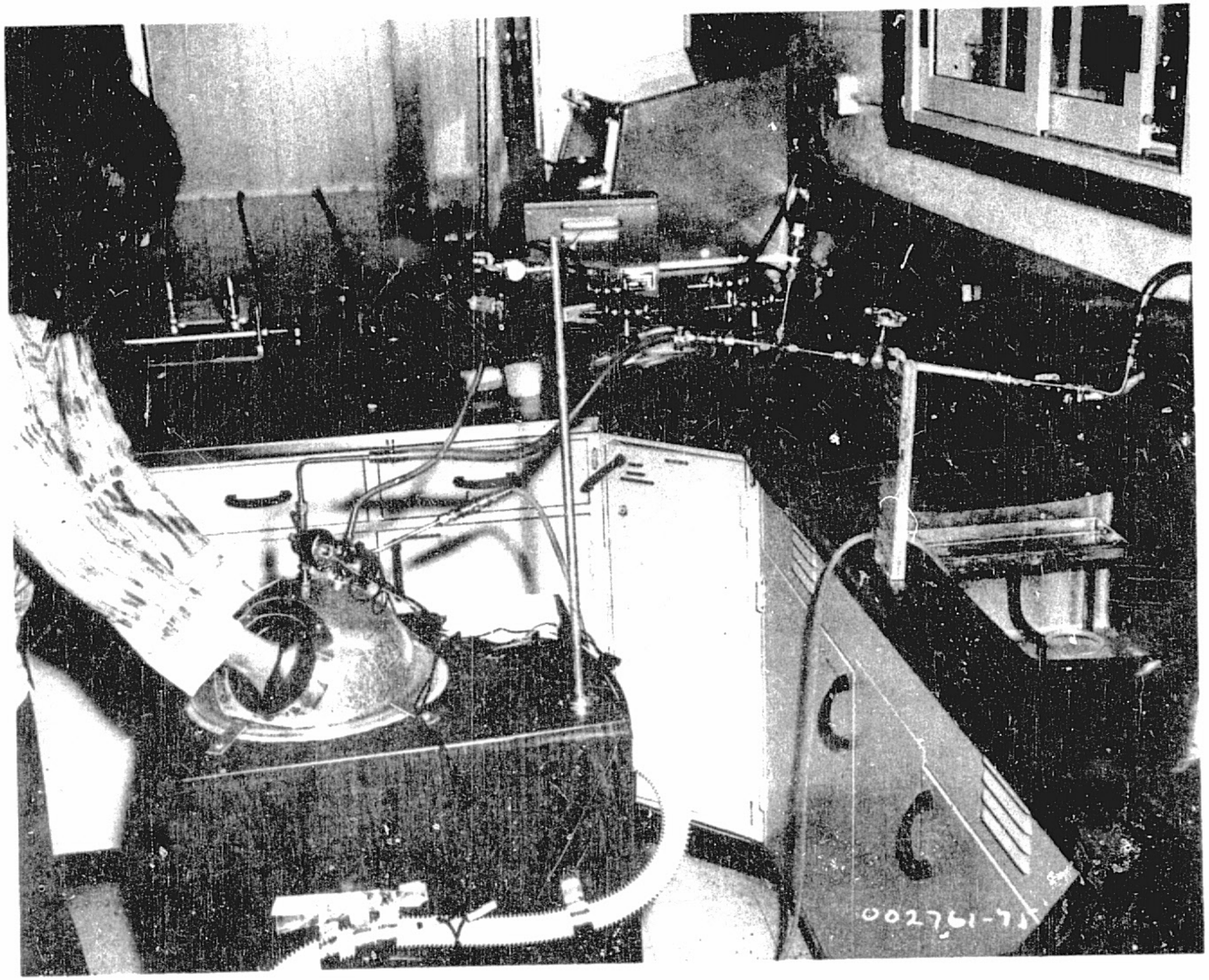

FIGURE IV-3 SIDE VIEW OF UTENSIL/HAND CLEANSING TEST FIXTURE

- o Wet and dry bulb thermometers were placed in the hose connecting the Liquid Gas Separator and the blower so that the change in grains per pound of dry air for the air leaving the LGS could be determined.
- o Permanent hand hole coverings were placed on the fixture to prevent water leakage.
- o A smooth inside hose was installed between the basin drain and the LGS so that water would not be trapped as before in the convolutions in the hose. This obtained a closer output yield to the input for the water balance tests.

Table IV-1 is the equipment utilized during the testing.

Table IV-1 Test Equipment Hardware

Component	Vendor/ Part No.	Specification
Test Fixture	MMC Fab.	See Figure II-1
Blower	Rotron CHE-4	92CFM @ 56" H_2O
Solenoid Valves	Peter Paul Co. No. 3208DGVS	120 VAC, 60 cycle 60 psi, 2 way, N.C.
Nozzle	Bete W5080	Hollow, .20 gpm@ 20 psig
Control Switch	McMaster-Carr No. 7376K1	115 VAC, 7 amps
Vortex LGS	MMC70-98784-1	0-40 CFM Air, 0-26 Pm H_2O
Beaker/Burette	Lab Equipment	0-600 ML/0-25 ML
Pressure Gage	Hoke	0-300 psi
Hand Valves	Lab Equip	
Thermometers	Lab Equip	0-22^{o}F, 2^{o}F, -10^{o}C to 55^{o}C
Stop Watch	Lab Equip	
Hemisphere Dome	MMC Fab.	Plexiglass 12" Dia.
Truncated Cone	MMC Fab.	Plexiglass 6"x12" Dia.
Towel	Lab Equip	18'x24' Cotton Cloth & 10½"x14" Paper
Airmeter	Anemostate Model 60 anemotherm	Air Velocities to 8000 FPM temperatures to 225^{o}F static pressures to 8.0" H_2O
U-Tube	Lab Equip	0-20 inches water
Weight Scale	Lab Equip	0-50 grams, .1 gram
Sling Psychrometer	Bacharach 12-2006	30^{o} to 110^{o}F.

2. Microbial Burden and Disinfection Studies Material Preparation

a. Cotton Swabs - Score cotton swabs 2 to 3 cm above the swab and place in test tubes with caps. Autoclave at 1.38×10^5 N/m^2 (20 psi) for 900 seconds (15 minutes) to sterilize.

b. Sample and dilution tubes containing 10 ml and 9 ml of phosphate buffered saline respectively. Autoclave at 1.38×10^5 N/m^2 (20 psi) for 900 seconds (15 minutes) to sterilize.

c. Solidified nutrient medium for microorganisms.

1) Prepare Trypticase Soy Agar (TSA). TSA is a general purpose solid medium supporting the growth of a wide variety of microorganisms. Weigh out 30 g of concentrate and add to 750 ml of distilled water. Cap with a cheesecloth covered cotton plug and autoclave 1.38×10^5 N/m^2 (20 psi) for 900 seconds (15 minutes) to sterilize.

2) Prepare Petriplates containing TSA. After sterilization, place the flasks of TSA in a hot air oven at 45°C to temper (i.e., cool to a point just above solidification). When tempered, using aseptic technique in a clean area, manually pour about 25 ml of molten TSA into each Petri plate. Allow to solidify and cool before storage.

d. Disinfection Solutions

1) Olive Leaf Solution - Based on an average use of 1 part of 20% olive leaf to 90 parts of water.

2) Wescodyne Solution - A general cleaning and disinfecting solution is prepared by adding .085 kg (3 oz) of Wescodyne to .019 m^3 (5 gallons) of water. The solution prepared for these tests is the same concentration (4.7 ml of Wescodyne/liter).

3) Sodium Meta-bisulfite - The solution was prepared by dissolving 1.0 g of the salt in a liter of distilled water.

e. Stainless Steel Coupons Seeded with <u>Escherichia coli</u> Strain Seattle - Three stainless steel coupons 51.6 cm^2 (eight inches square) were marked with six 51.6 cm^2 (4 sq inch) areas (Figure IV-4). The plates were individually wrapped and sterilized by autoclaving. Seeding the surface was accomplished by spraying all three plates with 6.5 ml of a two day old culture of the bacteria.

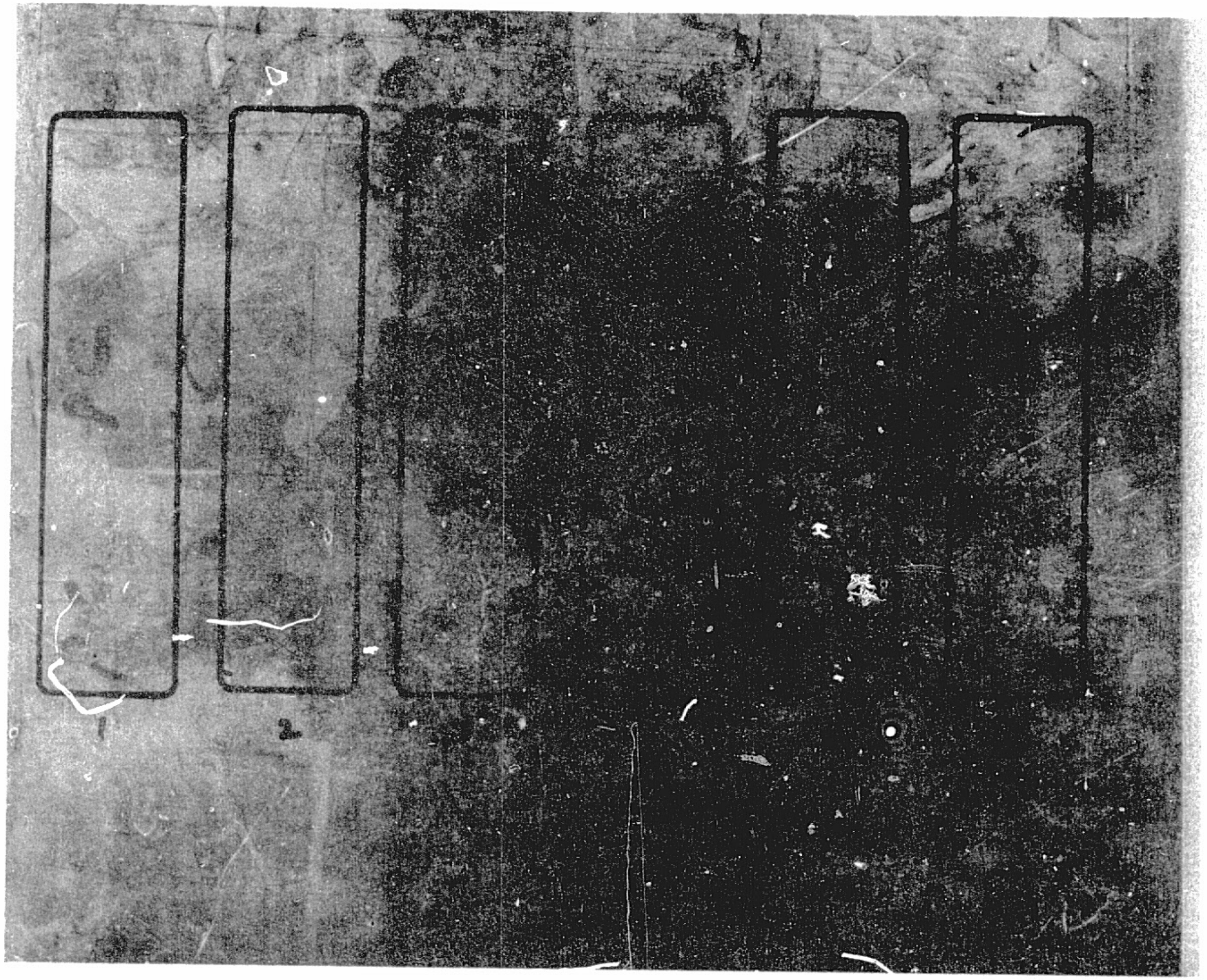

FIGURE IV-4 STAINLESS STEEL COUPONS

3. <u>Waste Chemical Fluid Disposal and Control of Evolved Gases</u> - Since some of the waste fluids are toxic, their transfer to the cleansing fixture shall be in a sealed container. This sealed container shall be designed to allow manual fluid transfer and have a pouring goose-neck nozzle that can interface with the fixture's waste collection inlet drain. This would allow the waste fluid to be transferred directly into the waste collection system by the air drag. If the liquid was poured openly into the enclosure, a small portion may have to be moved manually with a crewman's hands or other special hand tool toward the drain. This may not be compatible with the crewman's health.

The following list of liquid chemicals are generally utilized in a life sciences laboratory and are used to size the charcoal filter that will be utilized to remove contaminants or objectional odors from the process air prior to its return to the cabin environment.

Acetic acid	$C_2H_4O_2$
Acetone	C_3H_6
Benzene	C_6H_6
Carbon disulfide	CS_2
Carbon tetrachloride	CCl_4
Chloroform	$CHCl_3$
Cyclohexanal	$C_6H_{12}O$
Cyclopentane	C_5H_{10}
Dioxane	$C_4H_8O_2$
Ethyl acetate	$C_4H_8O_2$
Ethyl alcohol	C_2H_6O
Methylene chloride	CH_2Cl_2
Methyl n-propyl ketone	$C_5H_{10}O$
Trichlorothylene	C_3HCl_3

To conduct the test, 20 ml of the material was dumped into the bottom of the fixture with the blower on at 26.5 m^3/sec (15.58 CFM). The time was recorded from the dump until the last drop fell into the graduated cylinder at the bottom of the sump.

C. TEST DATA

Testing consisted of establishing water usage criteria, soap usage criteria, timeline data and other quantitative criteria (water lost to ambient, water left in system, water transferred to towel, water nozzle flow rate, man-machine interaction) during a utensil cleansing, hand-washing, shaving, teeth brushing, mouth rinsing, apparel washing and a "sponge-bath" type body wash. Also microbial burden and disinfection studies and chemical fluid dumping were conducted which consisted of determining what microbial burden is generated in the fixture by short term use and determining the effectiveness of selected disinfectants in reducing the microbial burden. The data obtained from the testing is summarized below.

1. Water Nozzle Flow Rate - The purpose of these preliminary tests was to determine spray pattern/hand interface comfort factors and flow rates for a 137.9×10^3 N/m^2 (20 psig) pressure head. The following is a summary of the tests:

NOZZLE	SPRAY PATTERN	FLOW RATE m^3/s x 10^{-5} (gpm)	PRESS. N/m^2 x 103 (psig)	RINSE/COMFORT FACTORS
SS 40015	Flat	.650 (.103)	137.9 (20)	Poor - Soft Spray
SS 4001	Flat	.404 (.064)	137.9 (20)	Poor - Underdeveloped Spray
SS 4002	Flat	.801 (.127)	137.9 (20)	Good - Soft Spray
SS 4002 (Mod.)	Flat	.820 (.130)	137.9 (20)	Poor - Soft, Underdeveloped
SS 4004	Flat	1.748 (.277)	137.9 (20)	Good - No Sting
SS 4006	Flat	2.499 (.396)	137.9 (20)	Good - Tickling Sensation
SS 4015	Flat	5.616 (.890)	137.9 (20)	Good - Course Feeling
SS 4020	Flat	7.320(1.16)	137.9 (20)	Good - Very Course
D .20/40°	Hollow Cone	.801 (.127)	137.9 (20)	Poor - Soft Spray
D .10/40°	Hollow Cone	.404 (.064)	137.9 (20)	Poor - Soft Spray
D 35040	Flat/ Angle	1.401 (.222)	137.9 (20)	Good - Very Course
B-W5080H	Hollow Cone	1.578 (.250)	137.9 (20)	Good - Soft Spray

SS - Spraying Systems, Inc.; D - Delevan; B - Bete

The objective of the fixture is to perform the tasks desired with minimum water usage and maximum comfort. The two nozzles that achieve a good rinse and soft spray are SS 4002 and B-W5080H. These two nozzles were further evaluated in respect to wetting and the B-W5080H was found to be optimum from a water usage and comfort for wetting. The nozzle B-W5080H was selected for use and further flow rate testing was performed. The nozzle then was found to have a flow rate of 11 ml/sec (.17 gpm) at 10.34 x 10^4 N/m^2 (15 psig) and 12.5 ml/sec (.20 gpm) at 13.8 x 10^4 N/m^2 (20 psig).

2. Water Balance - Test for water balance for both 10.34 x 10^4 N/m^2 and 13.8 x 10^4 N/m^2 (15 psig and 20 psig) were conducted. Preliminary testing showed that the average wet time was 4 sec and the average rinse time was 10 sec, thus making a total time the water is on of 14 secs. For both water pressure conditions, the system was purged with water for 14 sec when it was completely dry. Wet and dry bulb readings were taken of the system air and ambient air and the water output was measured. The system was again purged with water for 14 sec immediately following the above test and the same data readings were taken. The system was again purged with water but this time with a man rinsing his hands for the 14 sec and then cleansing the enclosure and drying his hands on the towel. Again wet and dry bulb readings were taken and the water output was measured, as well as moisture transferred to the towel.

To obtain a count of the number of grains of moisture per pound of dry air lost to the ambient, wet and dry bulb readings were taken every 10 secs for 120 sec duration during the test. From the temperature readings, the change in grains from the ambient air was found by use of a psychrometric chart. Then the change in grains per pound of dry air (ΔG/#dA) was plotted against time as shown in Figure IV-5. The average wet and dry bulb readings and the corresponding ΔG are listed in Table IV-2. The area under the curve was determined and this represented the total Δ G/#dA lost to the ambient during the 120 secs. An average value was then determined to be 56.33 ΔG/#dA.

To find the number of grains lost to the ambient, calculate:
Blower Air Flow (CFM) x #dA/ft^3 x ΔG/#dA x Blower on Time

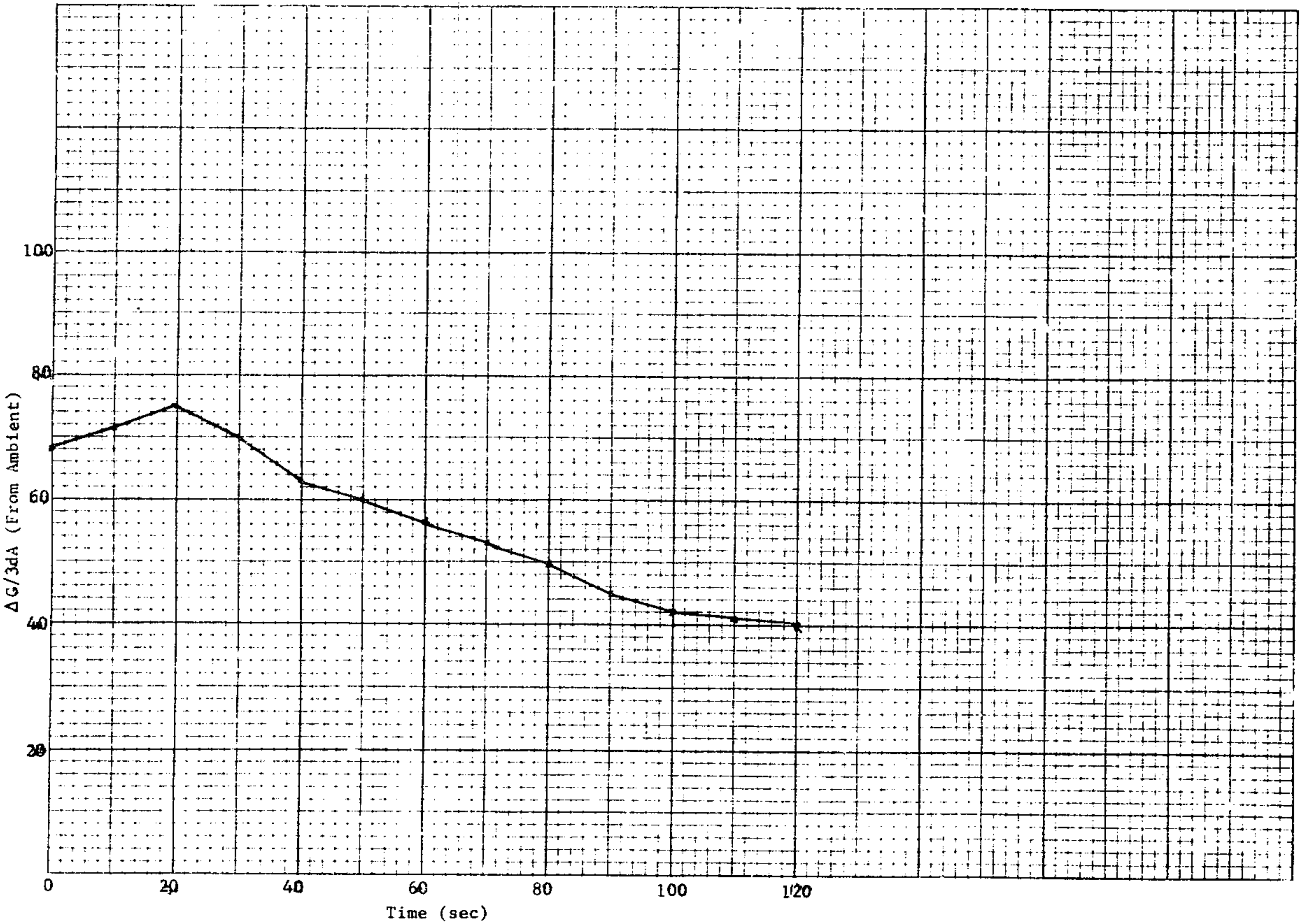

FIGURE IV-5 MOISTURE LOSS FOR CONTINUOUS 14-SEC SPRAY

TABLE IV-2 WET AND DRY BULB READINGS FOR CONTINUOUS 14-SEC SPRAY

	WET BULB °K (°F)	DRY BULB °K (°F)	ΔG/#dA from Ambient
Ambient	287.65 (58.1)	299.65 (79.7)	0
Time from blower start:			
0	294.05 (69.62)	298.71 (78)	68
10	294.45 (70.34)	298.84 (78.25)	71.5
20	294.75 (70.88)	298.84 (78.25)	75.5
30	294.25 (69.98)	298.71 (78)	70
40	293.55 (68.72)	298.71 (78)	62.5
50	293.45 (68.54)	298.57 (77.75)	61.5
60	293.05 (67.82)	298.57 (77.75)	57
70	292.7 (67.19)	298.43 (77.5)	53.5
80	292.4 (66.65)	298.43 (77.5)	49.5
90	291 95 (65.84)	298.43 (77.5)	45
100	291.95 (65.84)	298.43 (77.5)	45
110	291.65 (65.3)	298.43 (77.5)	42
120	291.5 (65.03)	298.3 (77.25)	41
	291.4 (64.85)	298.3 (77.25)	40

This equals:

$$\frac{15.58 \text{ cu ft}}{\text{min}} \times \frac{.06 \ \#\text{dA}}{\text{ft}^3} \times 56.33 \ \Delta G/\#\text{dA} \times 2 \text{ min} = 105.3 \ \Delta G$$

To find the amount of water (ml) lost to the cabin environment, multiply the above number by 6.48×10^{-2} ml/ΔG to obtain 6.8 ml.

Both of the values calculated above were found to be approximately equal both at 13.8×10^4 N/m^2 (20 psi) and 10.34×10^4 N/m^2 (15 psi) nozzle flow pressures.

The number of grains left in the system atmosphere is simply the end point of the curve in Figure IV-5 at 120 secs. This is 40 grains/#dA. The system volume was calculated to be .397 ft^3.

$$\# \text{ grains} = .397 \text{ ft}^3 \times \frac{.06 \text{ lb dA}}{\text{ft}^3} \times \frac{40 \text{ grains}}{\text{lb dA}} = .953$$

The water left to the system atmosphere is then, .953 grains x 6.48×10^{-2} ml/grains = .062 ml.

The amount of water delivered by the nozzle was found by multiplying the time the nozzle was flowing water (14 secs) by the flow rate from the nozzle performance curve for the designated psi. For 13.8×10^4 N/m^2 (20 psi), this was 14 secs x 12.5 ml/sec = 174 ml and for 10.34×10^4 N/m^2 (15 psi), this was 14 secs x 11 ml/sec = 154 ml. The unaccounted water was found by adding together amount of water collected, amount of water lost to ambient, amount of water left in system atmosphere, amount of water transferred to towel and subtracting it from the amount of water delivered to the system. The results of the water balance test for a dry system, a wet system and a wet system with a man-machine interface are presented in Table IV-3.

3. Temperature Limits - The maximum allowable water temperature on a back of a hand was found by having the subject place the back of his hand under hot running water and recording the time until the subject experienced pain and would remove their hand voluntarily. The temperature of the water was slowly decreased until that maximum water temperature was found which could be endured for long periods of time ($>$40 sec).

Results of these tests are summarized in Table IV-4 in which the values listed under the temperatures are how long the subject could place the back of his hand in water at that temperature.

The comfortable temperature that a subject could place his hands under a hand dryer was found to be approximately 330.15°K (134.6°F). (Varied with distance from blower outlet, average distance 101.6mm (4").) The degree of wetness of the user's hands was also a crucial factor since if the user's hands were dry, he could not tolerate the above temperature for the same period of time as did a user with fairly wet hands.

TABLE IV-3. RESULTS OF WATER BALANCE TESTS

	Dry System		Wet System		Wet System with Man-Machine Interface	
	13.8×10^4 N/m^2 (20 psi)	10.34×10^4 N/m^2 (15 psi)	13.8×10^4 N/m^2 (20 psi)	10.34×10^4 N/m^2 (15 psi)	13.8×10^4 N/m^2 (20 psi)	10.34×10^4 N/m^2 (15 psi)
Amount of water delivered by nozzle in 14 secs (ml)	174	154	174	154	174	154
Amount of water collected (ml)	166	134	169	146	168	138
Amount of water lost to ambient air (approximately) (ml)	6.8	6.8	6.8	6.8	6.8	6.8
Amount of water lost to system atmosphere (ml)	.062	.062	.06	.062	.062	.062
Amount of water transferred to towel (g)	-	-	-	-	2.6	1.5
Total water accounted (ml)	172.862	140.862	175.862	152.862	177.462	146.362
Water un-accounted (ml)	1.138	13.138	-1.862	1.138	-3.462	7.638

TABLE IV-4. WATER TEMPERATURE LIMITS

	TEMPERATURE						
Test No.	324.82°K (125°F)	322.04°K (120°F)	321.5°K (119°F)	320.93°K (118°F)	320.4°K (117°F)	319.82°K (116°F)	319.3°K (115°F)
1	1.6 sec	2.5 sec	4.5 sec	9.5 sec	*		
2	2.2 sec	8.0 sec	-	15.4 sec	*		
3	1.5 sec	2.8 sec	4.0 sec	*			
4	1.7 sec	4.5 sec	6.9 sec	7.7 sec	11.4 sec	*	
5	1.9 sec	1.5 sec	4.9 sec	5.3 sec	12.5 sec	*	
6	0.9 sec	3.4 sec	4.0 sec	4.6 sec	11.4 sec	10.1 sec	*
7	1.4 sec	3.4 sec	5.0 sec	17.2 sec	2.7 sec	*	
8	2.8 sec	6.4 sec	7.0 sec	19.1 sec	*		
9	4.5 sec	13.1 sec	12.5 sec	31.0 sec	*		

* Maximum temperature at which subject felt he could stay at for long periods of time.

4. Fixture Test Task - The test procedures for the man-machine interfacing, establishment of criteria ranges and miscellaneous testing were performed on the test fixture shown in Figure IV-1 and consisted of having a test subject perform tasks that a crewman might perform in a zero-gravity environment. For the performance of each task, the subjects were instructed on the methods desired. A surgical wash technique in which every finger is carefully cleaned was utilized for handwashing and a normal washing with a manual removal of excess water was employed for the utensil cleansing. Those tasks that were performed are listed below along with the various steps involved in the task:

- Handwashing
  - o Wet hands
  - o Soap hands
  - o Wash
  - o Rinse
  - o Remove excess water from the enclosure
  - o Dry hands

- Laboratory Knife Washing

  - o Wet knife
  - o Soap knife
  - o Wash
  - o Rinse
  - o Remove excess water from knife
  - o Dry knife
  - o Remove excess water from enclosure
  - o Dry hands

- Apparel Washing

  - o Wet apparel
  - o Apply soap
  - o Wash
  - o Rinse
  - o Remove excess water from apparel
  - o Remove excess water from enclosure
  - o Dry hands

- Shaving

  Each test subject was allowed to follow his own normal routine.

- Teeth Brushing

  - o Wet tooth brush
  - o Apply baking soda
  - o Brush teeth
  - o Discharge excess from mouth into fixture
  - o Repeat above steps until satisfied
  - o Rinse toothbrush
  - o Rinse mouth
  - o Remove excess water from enclosure
  - o Dry hands

- Hair Wetting

  - o Wet hands
  - o Apply water to hair
  - o Remove excess water from enclosure
  - o Dry hands

- Body Wash

  - Wet wash cloth
  - Clean skin areas desired
  - Rinse wash cloth
  - Repeat above steps until satisfied
  - Remove excess water from enclosure
  - Dry hands

In all of the above tasks, the system is also required to be activated and then deactivated upon completion of the tasks. In the first three tasks mentioned above, each step of the task was timed and recorded whereas the other tasks were timed in their entirety.

The anthropometric dimensions of the test subjects were:

Height:	157.5 cm - 193 cm (5'2" - 6'4")
Weight:	53.1 - 95.3 kg (117 - 210 lbs)
Age:	22 - 49 years
Sex:	M - F

The results of the tests are summarized in the following paragraphs.

a. Handwashing - Twenty handwashings (9 females, 11 males) were performed in which each subject was timed on obtaining water, obtaining soap, washing, rinsing, cleaning the enclosure, and drying. Also, water temperature, soap usage, total water collected and water left on towel were recorded. Again, these tasks were performed for nozzle pressures of 10.34×10^4 N/m^2 (15 psi) and 13.8×10^4 N/m^2 (20 psi) conditions. The cycle times, total soap usage, total time required to perform the task, water transfer to towel and total water collected are summarized in Table IV-5. The total water collected is the amount of fluid collected minus the soap usage.

TABLE IV-5. HANDWASHING TEST RESULTS

CYCLE TIMES (SEC)	13.8×10^4 N/m^2 (20 psi)			10.34×10^4 N/m^2 (15 psi)		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Wet	1.8	4.0	8.5	2.0	3.8	6.3
Soap	1.6	2.7	5.2	1.7	3.3	6.2
Wash	12.0	16.1	22.7	6.7	11.8	17.0
Rinse	9.3	12.0	17.0	5.7	12.8	22.0
Clean	7.0	18.5	30.0	8.5	13.7	27.3
Dry	10.8	27.5	27.2	8.2	12.0	20.4
Soap Usage (ml)	0.8	1.5	2.4	0.55	2.0	3.4
Total Time (sec)	52.2	71.1	100.0	42.9	57.4	70.4
Total Water Collected (ml)	130	181	238	60	155	249
Water Transferred to towel (ml)	1.6	2.6	3.6	1.7	2.2	3.1
Total Water Delivered	152.5	200	277.5	86.9	182.6	303.6

Water balance tests were also conducted during the handwashing task. To facilitate the recording of data, wet and dry bulb temperature readings of the blower air were recorded when the system simulated a handwashing (the system was purged for 4 secs to simulate a wet cycle, then purged again for 10 secs (rinse) 24 secs later, which allowed for soap and wash cycle). By use of a psychrometric chart Δ G/#dA were obtained and plotted against time as in Figure IV-6. The wet and dry bulb readings, with their corresponding Δ G/#dA above ambient, are recorded in Table IV-6 The area under the curve in Figure IV-6 was determined and ΔG was calculated in the same manner as in Section IV-B. The total ΔG/#dA for 120 secs (time blower on) is 5723 or 47.69 grains/sec. Therefore; ΔG lost to ambient = 15.58 ft^3/min x .06 #dA/ft^3 x 47.69 x $\frac{1 \text{ min}}{60 \text{ sec}}$ = .74 grains per unit time. For the total 120 secs, this amounts to .74 x 120 = 89.2 grains. To convert this to milliliters, multiply 89.2 grains x 6.48×10^{-2} ml/grain = 5.78 ml.

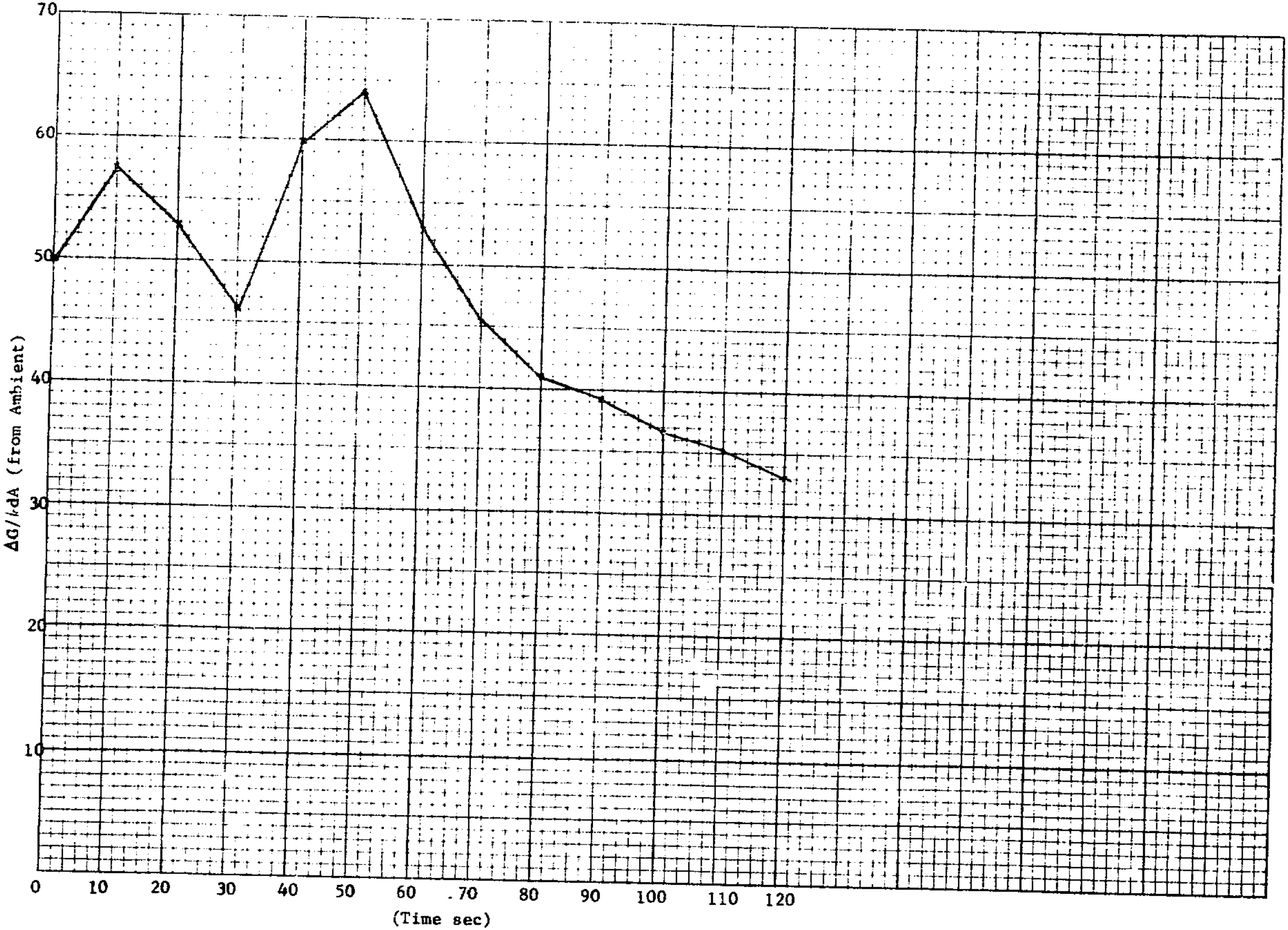

FIGURE IV-6. MOISTURE LOSS FOR WET RINSE CYCLE (4-10 SEC)

TABLE IV-6. WET AND DRY BULB READINGS FOR WET-RINSE CYCLE (4-10 SEC)

	Wet Bulb °K (°F)	Dry Bulb °K (°F)	ΔG/#dA Above Ambient
Ambient	286.15 (55.4)	296.15 (73.4)	0
Time from blower start:			
0	291.5 (65)	295.93 (73)	50
10	292.25 (66.38)	295.93 (73)	57.6
20	291.75 (65.5)	295.93 (73)	53.3
30	291.15 (64.4	295.93 (73)	46
40	292.42 (66.68)	295.93 (73)	55
50	292.85 (67.46)	295.93 (73)	61.3
60	291.72 (65.42)	295.93 (73)	53
70	291.12 (64.34)	295.7 (72.6)	43
80	290.65 (63.5)	295.65 (72.5)	41
90	290.38 (63)	295.65 (72.5)	39.3
100	290.18 (62.66)	295.65 (72.5)	36.6
110	290 (62.3)	295.65 (72.5)	35.16
120	289.8 (61.94)	295.65 (72.5)	33.3

The number of grains left in the system atmosphere is the end point of the curve at 120 secs (33.3 grains/#dA). With the system volume equal to .397 ft^3, then the grains lost is .397 ft^3 x .06 #dA/ft^3 x 33.3 grains/#dA = .79 grains. Converting this to milliliters yields .79 grains x 6.48 x 10^{-2} ml/grain = .052 ml.

The above values were relatively the same for both 13.8 x 10^4 N/m^2 and 10.34 x 10^4 N/m^2 (20 and 15 psi) conditions. For wet-rinse times under or in excess of 14 secs, the moisture lost is a linear function (i.e., for wet rinse of 7 secs the moisture lost to the ambient air is half of 5.78 ml of 2.89 and the moisture left in the system atmosphere is .026 ml) (see Figure IV-7).

Using the above calculations, wet-rinse times, water transfer to towel and nozzle flow rate, the water balance results occurring during handwashing activities are listed in Table IV-7.

Table IV-8 shows a comparison of the average cycle times, soap usage and water usage, for one man and nine female test subjects. The test data shown was obtained at a water pressure of 10.34 x 10^4 N/m^2 (15 psi) only.

b. Laboratory Knife Washing - Seventeen utensil (lab knife) cleansings at 10.34 x 10^4 N/m^2 (15 psi) were performed in which each subject was timed on obtaining water, obtaining soap, washing, rinsing, removing excess water from the knife, cleaning the enclosure, and drying their hands. The amount of soap, water, and time used depended on the degree of dirtiness of the knife (substances used to soil the knife were lotion, dried coffee, and frog feces) as can be seen in Table IV-9 in which the average values are given only.

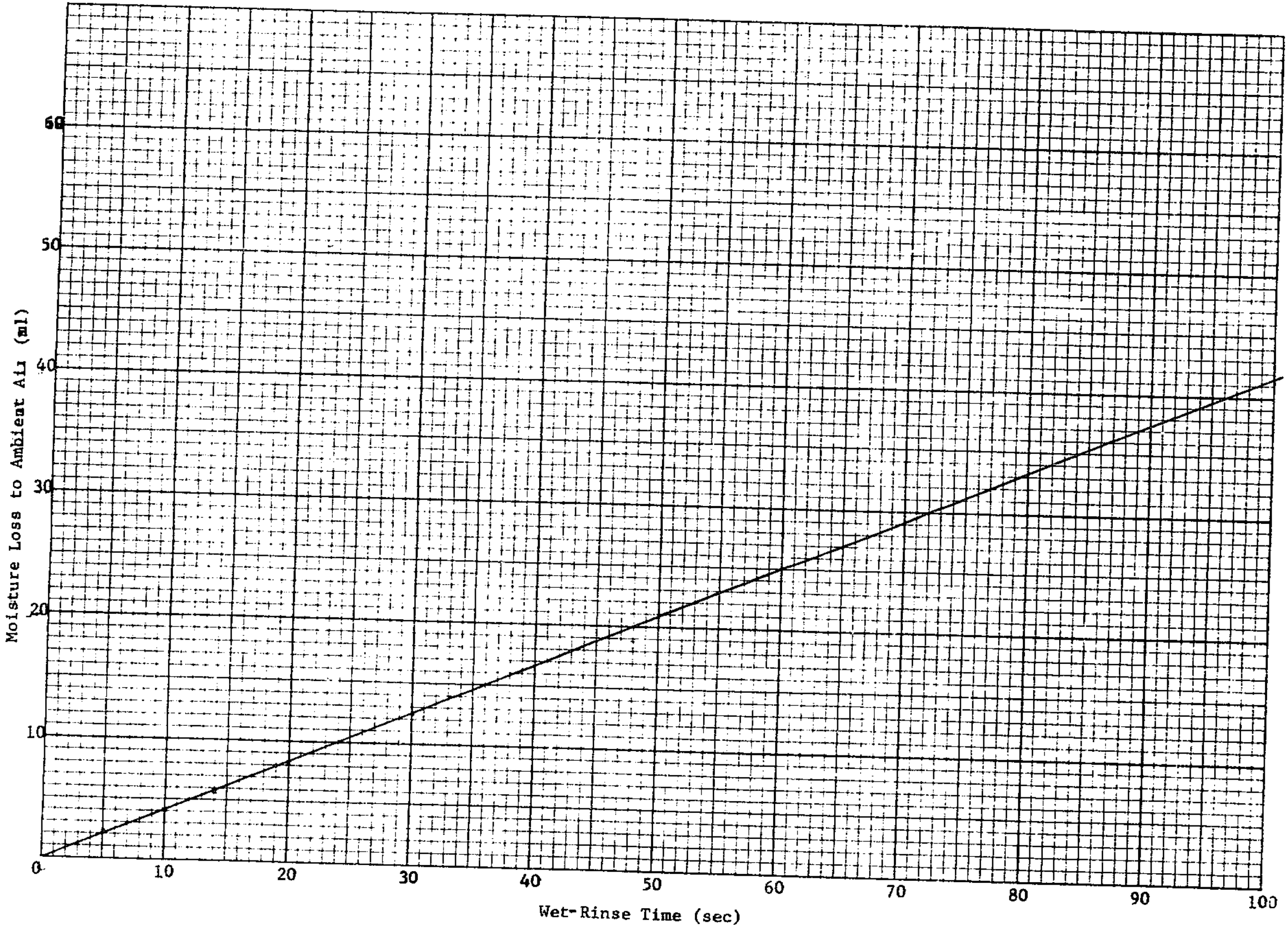

FIGURE IV-7. LINEAR RELATIONSHIP OF WET-RINSE TIME AND MOISTURE LOSS TO AMBIENT AIR

TABLE IV-7. WATER BALANCE FOR HANDWASHING ACTIVITY

	13.8×10^4 N/m^2 (20 psi)			10.34×10^4 N/m^2 (15 psi)		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Wet-Rinse Time (sec)	12.2	16.0	22.2	7.9	16.6	27.6
Total Water Collected (ml)	130	181	238	60	155	249
Water Transferred to Towel for Corresponding Wet-Rinse Time (ml)	2.2	2.6	1.6	2.2	2.2	2.6
Water Lost to Ambient (ml) Corresponding to Wet-Rinse Time	5.04	6.61	9.17	3.26	6.85	11.4
Water Left in System Environment (ml) Corresponding to Wet-Rinse Time	.0454	.06	.083	.03	.062	.103
Water Delivered to System (ml)	152.5	200	277.5	86.9	182.6	303.6
Total Water Accounted (ml)	137.3	190.3	248.85	65.49	164.1	263.1
Unaccounted Water (ml)	15.2	9.7	28.65	21.41	18.5	40.5

TABLE IV-8. COMPARISON OF DATA OBTAINED FROM MALE AND FEMALE TEST SUBJECTS

	MALE	FEMALE
CYCLE TIME (SEC):		
Wet	6.0	3.2
Soap	3.1	3.36
Wash	16.5	10.6
Rinse	21.4	10.7
Clean Enclosure	12.2	15.62
Dry	8.6	12.8
Total Time (sec)	67.9	54.73
Soap Usage (ml)	1.83	2.02
Water Transferred to Towel (ml)	2.85	1.98
Water Delivered to System (ml)	301.4	152.9

TABLE IV-9. COMPARISON OF DATA FOR VARYING KNIFE CONDITIONS

Knife Condition Data	Clean	Lotion	Dried Coffee	Frog Feces
WASH CYCLE (SEC):				
Wet	2.6	2.5	2.6	15.7
Soap	2.6	2.4	2.8	5.1
Wash	6.0	6.2	7.0	6.1
Rinse	8.7	5.8	3.8	7.6
Soap usage (ml)	1.0	1.0	0.9	3.1
Water collected (ml)	106	55.6	50	213
Water delivered to system (ml)	124.3	91.3	70.4	256.3

Table IV-10 summarizes the timeline data as well as the sum of the moisture loss. Moisture lost to the ambient and left in the system atmosphere are calculated in the same manner as in Section IVD-1 and Figure IV-6 (wet and dry bulb temperature readings were approximately equal, so Figure IV-6 could be used for these calculations). These values, along with average wet rinse times, are as follows:

Average wet rinse time (sec)	- 12.2
Total water collected (ml)	- 111.7
Water transferred to towel-knife drying (ml)	- .71
Water transferred to towel-hand drying (ml)	- 1.13
Moisture lost to ambient (ml)	- 5.4
Moisture left in system atmosphere (ml)	- .045
Total water delivered to system (ml)	- 134.2
Total accounted water (ml)	- 118.6
Total unaccounted water (ml)	- 15.6

TABLE IV-10. UTENSIL CLEANSING RESULTS

	Minimum	Average	Maximum
WASH CYCLE (SEC):			
Wet	1.3	4.2	29.0
Soap	1.4	3.2	7.4
Wash	1.5	8.9	30.5
Rinse	3.4	8.0	18.6
Remove water from knife	1.4	3.5	5.6
Dry knife	3.2	6.4	10.0
Clean enclosure	6.5	14.7	23.8
Dry hands	2.3	9.4	17.9
Total Time	28.2	58.8	90.2
Total Soap Usage (ml)	0.25	1.6	3.05
Water transferred to towel knife drying (ml)	.2	.71	1.5
Water transferred to towel hand drying (ml)	.5	1.13	1.6
Total Water Collected (ml)	41	111.7	350
Total Water Delivered (ml)	[illegible]1.7	134.2	523.6

c. <u>Personal Apparel Washing</u> - For this series of tests, subjects were timed on obtaining water, obtaining soap, washing the apparel, rinsing, removing the excess water from the apparel, cleaning the enclosure and then drying their hands.

Soap and water usage were also recorded. Two tests were performed in which subjects washed a dirty T-shirt. The average test results are as follows:

- Wash Cycle:

Wet	63.3 sec
Soap	30.3 sec
Wash	53.8 sec
Rinse	62.8 sec
Remove Excess Water	28.9 sec
Clean Enclosure	16.0 sec
Dry Hands	13.5 sec

o Total Time	268.5 sec
o Soap Usage	22.5 ml
o Total Water Collected	761 ml
o Water Left in T-Shirt	222.8 ml
o Water Transferred to Towel-Hand Drying	.3 ml
o Moisture Lost to Ambient Air	52 ml
o Moisture Left in System Atmosphere	.47 ml
o Total Accounted Water	1036.6
o Water Delivered to System	1387.1 ml (at 10.34×10^4 N/m^2) (15 psi)
o Unaccounted Water	350.5 ml

Comments were made by the test subjects that visibility and maneuverability within the enclosure was poor. A test was then conducted in which the test subject washed a pair of wool socks. The results of this test are summarized as follows:

- Wash Cycle:

Wet	34.3 sec
Soap	12.0 sec
Wash	76.4 sec
Rinse	66.4 sec
Remove Excess Water	19.8 sec
Clean Enclosure	17.7 sec
Dry Hands	10.4 sec
o Total Time	237 sec
o Total Soap Usage	9.2 ml
o Total Water Collected	918 ml
o Water Left in Socks	110.9 ml
o Water Transferred to Towel-Hand Drying	1.7 ml
o Moisture Lost to Ambient Air	41.6 ml
o Moisture Left in System Atmosphere	.37 ml
o Total Accounted Water	1072.57 ml
o Water Delivered to System	1107.7 ml (at 10.34×10^4 N/m^2) (15 psi)
o Unaccounted Water	35.13 ml

d. Shaving and Cleaning Razor - The shaving task was performed in the fixture with the enclosure top closed. The razor was cleaned by inserting it into the hand holes and placing it under a stream of water delivered at 13.8×10^4 N/m^2 (20 psi). Test subjects were allowed to shave in their normal manner. A self-heating shaving cream was used for all the shaving tasks. The shavers used were safety razors. A mirror was provided for personal ease.

The data obtained from these tests are summarized in Table IV-11. Moisture lost to the ambient air and left in the system atmosphere was found as in Section IV-1 and Figure IV-6.

e. <u>Brushing Teeth</u> - Table IV-12 summarizes the results of tooth brushing activities. To expectorate, the fixture dome was loosered from the base so that it could easily be moved to one side and then replaced for water flow. Baking soda was used as the toothpaste and each test subject used his own preference of tooth brushes. Each test subject was allowed to follow his usual routine for convenience. Times recorded were total time of task and the total time the water was spraying at 13.8×10^4 N/m^2 (20 psi). A pre-measured amount of water for rinsing the mouth upon completion of the brushing was supplied by a cup to simulate use of the drinking water dispenser to be used in future program plans. Moisture lost to the ambient air and left in system atmsophere are calculated as in IVD-1 and Figure IV-6.

TABLE IV-11. SHAVING TEST RESULTS

	Minimum	Average	Maximum
Total Time of Task (sec)	255.8	266.7	277.6
Total Water on Time (sec)	5[illegible] 2	54.5	58.8
Amount of Shaving Cream Used (ml)	2.8	4.65	6.5
Water Transferred to Towel (face and hand drying)(ml)	2.8	4.3	5.8
Total Water Collected (ml)	611.2	656.2	701.2
Moisture Lost to Ambient Air Line	20.7	22.5	24.3
Moisture Left in System Atmosphere (ml)	.19	.20	.22
Water Delivered to System (ml)	627.5	681.25	735
Total Accounted Water (ml)	632.09	678,9	725.72
Total Water Unaccounted (ml)	-4.59	2.35	9.28

TABLE IV-12. RESULTS OF BRUSHING TEETH TASK

	Minimum	Average	Maximum
Total Time of Task (sec)	119.1	142.35	165.6
Total Water on Time (sec)	7.0	11.5	16.0
Water Transferred to Towel-Hand and Face Drying (ml)	.5	.85	1.2
Total Water Collected (ml)	122	187	252
Moisture Lost to Ambient Air (ml)	2.9	4.75	6.6
Moisture Left in System Atmosphere (ml)	.026	.043	.06
Rinse Water (ml)	26.8	43.3	59.8
Water Delivered to System (ml)	87.5	143.75	200
Total Accounted Water (minus Rinse Water) (ml)	98.626	149.343	205.65
Unaccounted Water	-11.126	-5.6	-5.65

f. Wetting of Hair - Test subjects were instructed for this task to wet their hair sufficiently enough for shampooing (which they did not attempt). Water was obtained by placing the hands in the hand holes and drawing water out with the hands and applying it to the hair. Timed data included total time of task and total time the water was on. Moisture lost to the ambient air and left in the system atmosphere was calculated using Figure IV-6 . The results of the tests are summarized below:

Total Time of Task	- 88 sec
Total Water on Time	- 5.5 sec
Water Transferred to Towel-Hand and Hair Dry	- 6 ml
Total Water Collected	- 46 ml
Moisture Lost to Ambient Air	- 2.3 ml
Moisture Left in System Atmosphere	- .02 ml
Water Delivered to System (at 13.8×10^4 N/m^2 (20 psi))	- 68.75 ml
Total Accounted Water	- 54.32 ml
Unaccounted Water	- 14.43 ml

g. "Sponge-Type" Body Wash - Test subjects were instructed to wet a washcloth and use this to perform the wash. The amount of water utilized for this type of wash was 250 ml. The task was relatively easy to do, however, it was not performed in the cleansing fixture; therefore, a water balance test could not be conducted. The above figure may vary somewhat from one obtained using the cleansing fixture since rinsing and wetting of the washcloth would be performed at the same time.

5. Microbial Burden and Disinfectant Studies - A rough estimate of the microbial burden to be expected on the interior surfaces of the hand cleansing unit was obtained by assaying a portion of the surface for total microbial count. Three 25.8 cm^2 (4 sq in) areas were assayed. Three assays were performed. The first two were after 10 handwashings each. The third was after a variety of utensils (17), a pair of socks, and two T-shirts had been washed. Before the first set of 10 handwashings, the unit was disinfected with Wescodyne, rinsed with distilled water and wiped dry. After the handwashings, burden assays were made and the interior

surfaces of the unit were sprayed with Wescodyne solution until it beaded up on the surface. After about 1800 sec (30 min) the surfaces were rinsed with tap water and burden samples were again taken.

Table IV-13 summarizes the microbial burden as assayed after a series of 10 handwashings and after utensil and personal apparel cleansings before a disinfection solution was applied.

TABLE IV-13. MICROBIAL BURDEN ON THE UTENSIL/HAND CLEANSING FIXTURE

CONTRIBUTING TO BURDEN	MICROORGANISMS/SQ IN. (Microorganisms/cm^2)
First 10 hand washings	.65 (4.2)
Second 10 hand washings	.65 (4.2)
1[illegible] utensils, 1 pair socks, 2 T-shirts	8.02 (51.7)

After 19.5 ml of Wescodyne was sprayed onto the interior surfaces of the unit and allowed to be in contact with the unit for 1800 secs (30 minutes), burden samples were again taken showing a burden of .6 microorganisms/sq cm (3.8 microorganisms/sq in). Because of the low microbial burden found in the unit, an external model was set-up using stainless steel coupons seeded with an indicator organism, E. coli.

- o 25.8 cm^2 (4 sq in) areas of each coupon were assayed for total burden immediately before exposure to a solution.
- o The solutions were sprayed over the surface until they beaded up and were allowed to remain in contact with the coupons for a period of time. For each solution, this data is shown below.

	Volume	Contact Time	Plate No.
Olive Leaf	3 ml	40 min.	1
Wescodyne	6 ml	60 min.	2
Soldium Meta-bisulfite	6 ml	64 min.	3

The microbial burden on the test coupon just prior to application of the olive leaf solution was 3.1×10^3 microorganisms per square cm (2.0×10^4 microorganisms/square inch). After 2400 secs (40 minutes) of contact between the plate and olive leaf solution, there were 1.24×10^2 microorganisms/square cm (8.0×10^2 microorganisms/square inch).

The microbial burden on the coupon prior to exposure to Wescodyne was 2.33×10^2 microorganisms/cm^2 (1.5×10^3 microorganisms/square inch). After the Wescodyne had been on the surface for 3600 seconds (60 minutes), the burden was 0.0 microorganisms per square cm (0.0 microorganisms/square inch).

The microbial burden on the coupon prior to exposure to the sodium meta-bisulfite was 3.26×10^1 microorganisms/square cm (2.1×10^2 microorganisms/square inch). After the solution was sprayed and had been in contact for 3840 seconds (64 minutes), the burden was 0.0 microorganisms/square cm (0.0 microorganisms/square inch).

The control samples taken on the three coupons give an indication of the decrease in microbial population as a function of time and desiccation. This is shown in Figure IV-8.

6. <u>Maintenance</u> - Upon commencement of testing, the utensil/handwasher fixture was not in use for a period of time, both the soap solenoid and the LGS drain nozzle had to be cleaned due to the clogging of the olive leaf soap. However, once testing commenced, no further cleaning of these two items were necessary due to the soap clogging. The liquid gas separator had to be taken apart during testing once due to a foreign particle (silicone sealant used to seal the dome to the enclosure basin) clogging its drainage hole.

7. <u>Chemical Fluid Dumping</u> -

Testing was performed on chemical dumping into the fixture. For the purposes of this test, only those "waste chemicals" compatible with a Plexiglas liquid/gas separator could be used. In addition, only those materials already on hand were used. Four materials were tested:

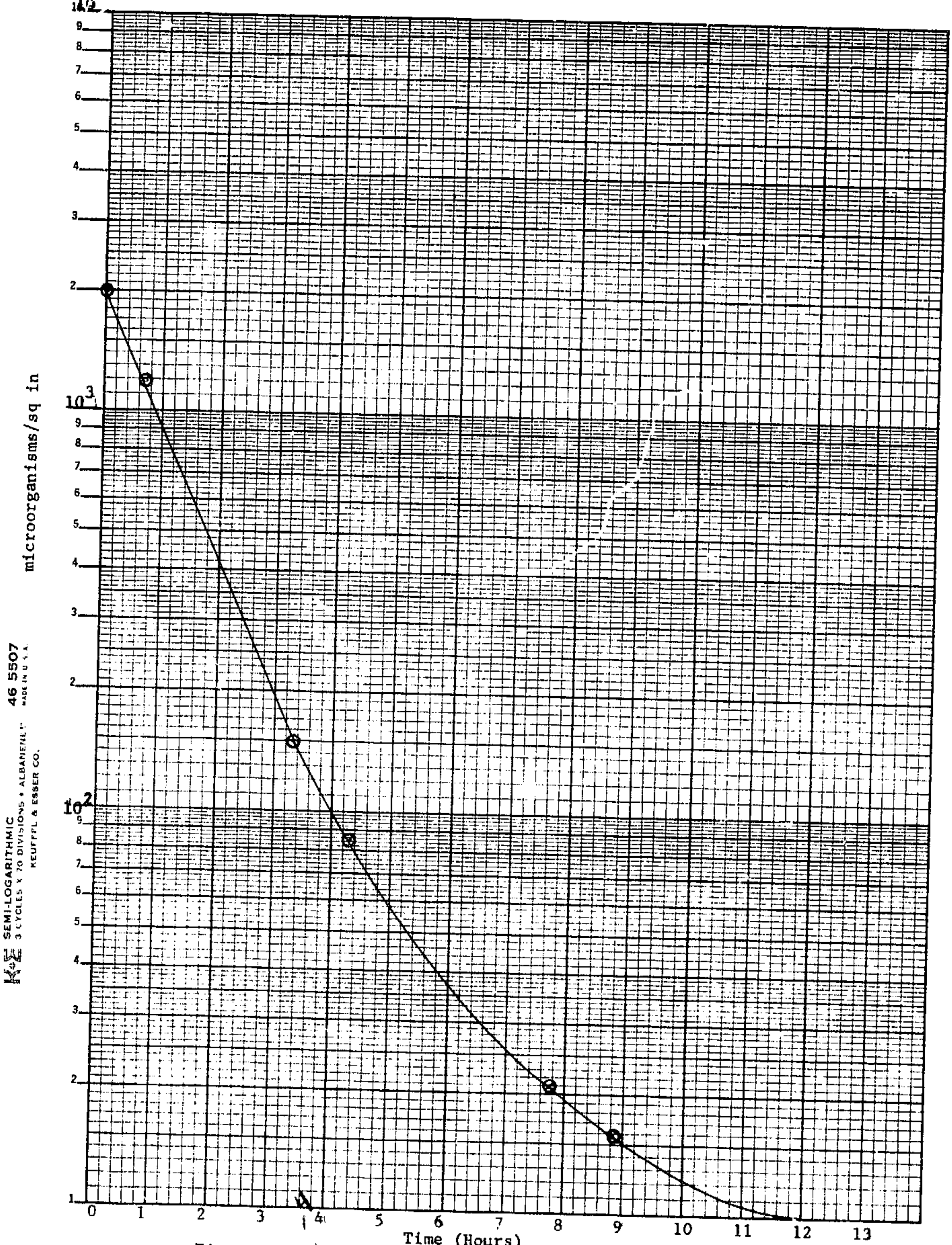

Figure IV-8 Die-Off Desiccation As A Function of Time

Ethyl Alcohol

Dioxane

Trichloroethane

5% Acetic Acid

The results of the test are tabulated in Table IV-14.

TABLE IV-14 MATERIAL COMPARISON

Material	Time (Sec)	m^3 (Cu Ft) Air	ml Collected	ml Vaporized	g Vaporized
Ethyl Alcohol	65	.48 (16.9)	10.2	9.8	7.735
Dioxane	55	.40 (14.3)	14.0	6.0	6.2
Trichloroethane	37	.27 (9.6)	12.5	7.5	10.824
5% Acetic Acid	40	.29 (10.4)	15.8	4.2	4.2

D. TEST DATA EVALUATION

1. Fixture Test Task - Comments made by a majority of the test subjects in favor of the present design include:

- o Comfortable to use
- o Good ease and comfort of obtaining water and soap
- o Air flow within the enclosure was comfortable
- o Hand holes were comfortable
- o Foot operated on-off switch preferred to knee, hand or forearm
- o Water and air temperature comfortable
- o The enclosure shape was adequate for maneuverability

Aesthetic aspects, visibility and placing objects in and out of the hemisphere dome enclosure was preferred to the tapered cylinder since there was excess volume. Many subjects commented that the enclosure height needed to be changed and that possible angling of the entire fixture would be beneficial in both visibility and ease of doing the task. However, it must be remembered that these feasibility tests were done in a one "g" environment and that the human body tends to form in a fetal position in a zero "g" environment, thus conforming more to the present design of the enclosure. Aside from these two comments, the Utensil/Handwashing fixture appears to be highly satisfactory as far as ease and comfort of performing a given task. Conclusions and limitations concerning each individual task are as follows:

a. Handwashing - Figure IV-9 shows a timeline schedule that could be used for automatic operation of the fixture for 13.8×10^4 N/m^2 (20 psi) based upon the test data. The times shown are for the average values obtained during testing. Figure IV-10 shows the timeline for the 10.34×10^4 N/m^2 (15 psi) condition. As can be seen from Table IV-8, for a handwashing, female test subjects utilized approximately half the amount of water male test subjects used, and took less time to complete the entire task. However, the female test subjects used more soap, took longer to clean the enclosure, and took longer to dry. The timeline data was computed from an average of data from both male and female test subjects. Test subjects made the comment that an automatic operation for the hand cleansing

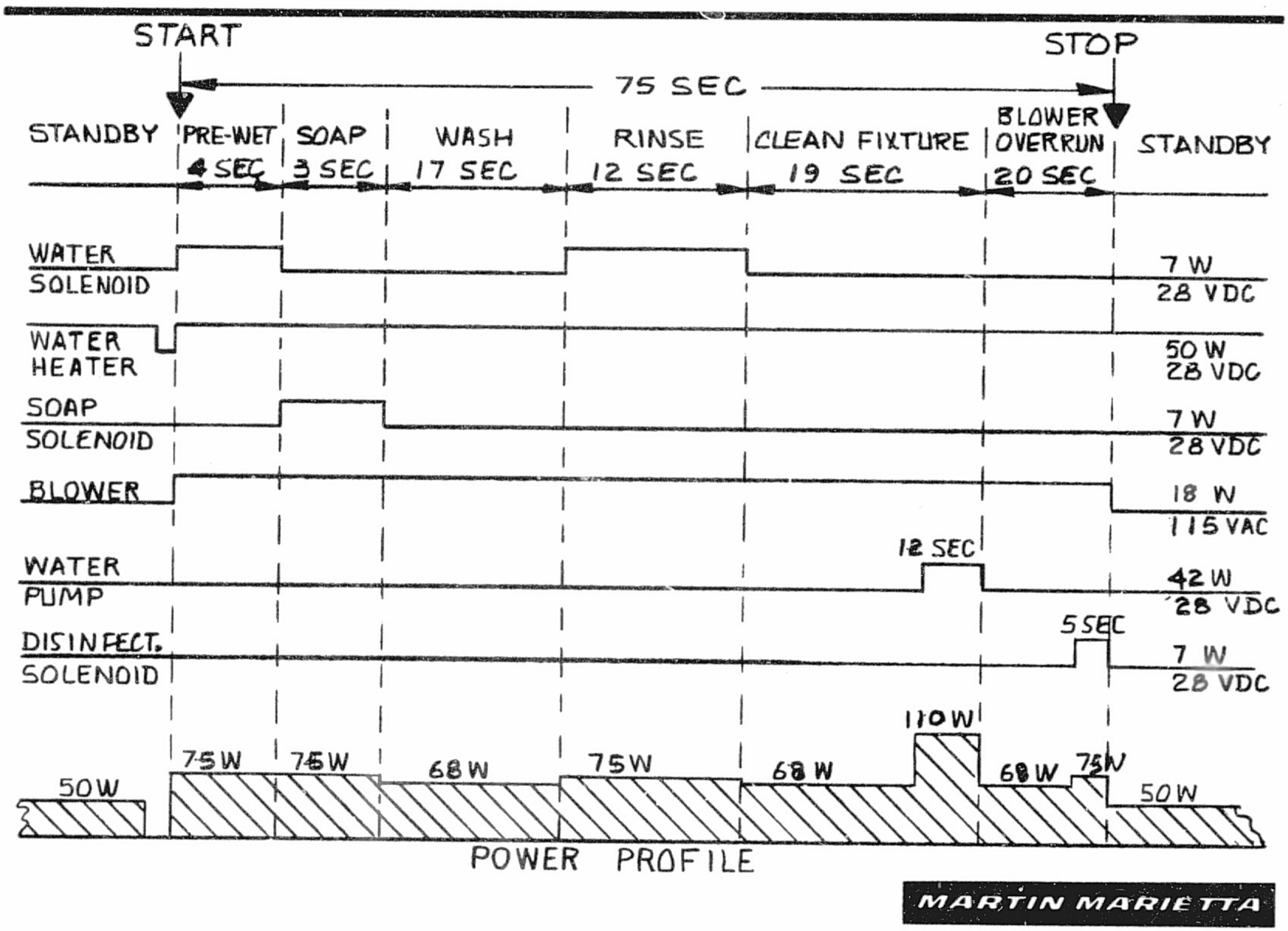

Figure IV-9 Automatic Operation Time Sequence for 13.8 x 10^4 N/m^2 (20 psi)

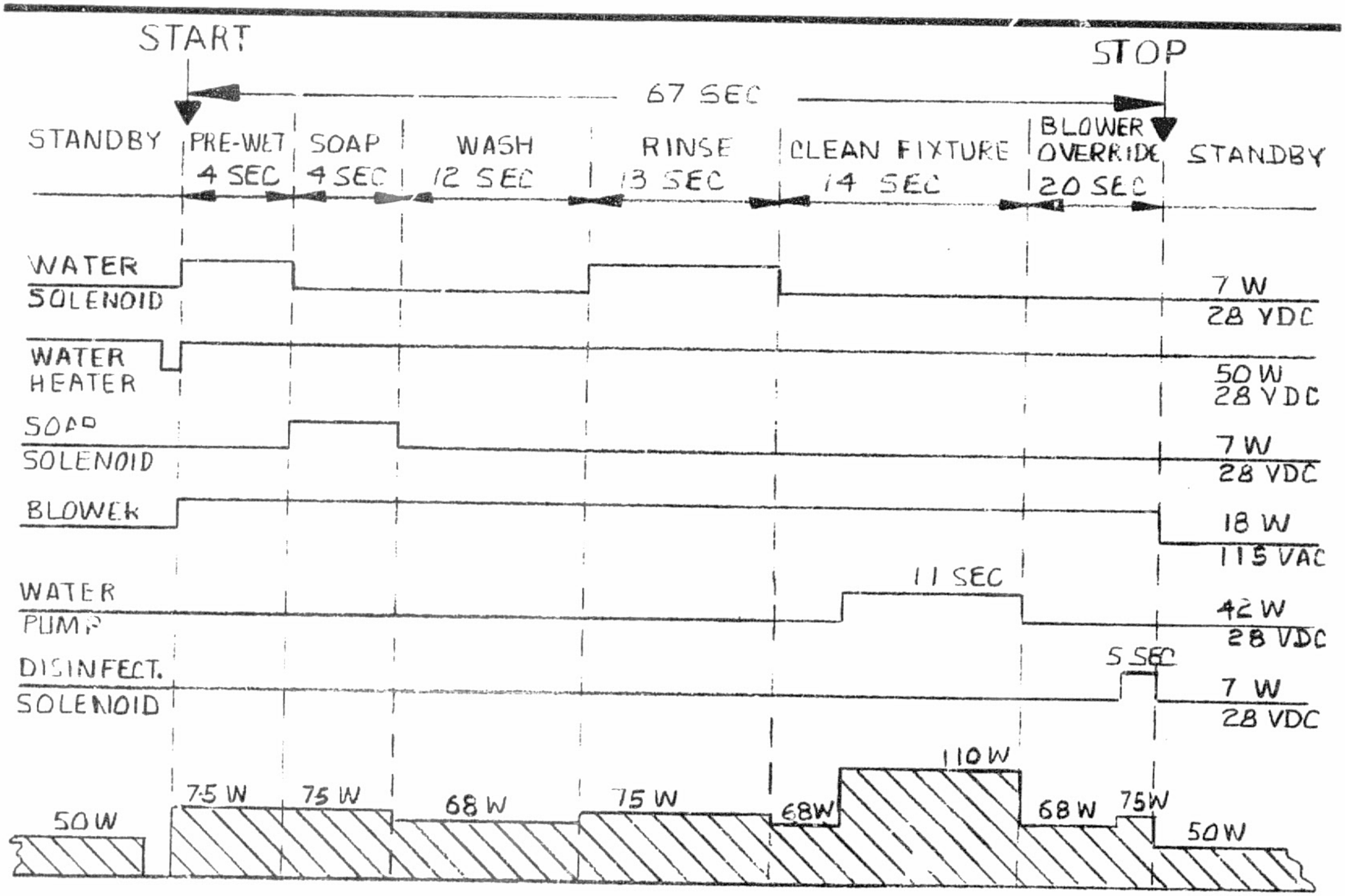

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Figure IV-10. Automatic Operation Time Sequence for 10.34×10^4 N/m^2 (15 psi) fixture was satisfactory, however, some comments were made that a timing device should be added to let the crewman know what time is left for that particular part of the cycle.

Using the average wet-rinse times for each pressure condition, the total water usage can be found. A nozzle that flows 12.5 ml (13.8×10^4 N/m^2 (20 psi)) for 16 seconds (see Table III-3) will have a total flow of 200 ml (.44 lb) (.053 gal) per washing. For the 10.34×10^4 N/m^2 (15 psi) condition, the average total flow is 182.6 ml (.4 lb) per washing. Using the average soap usage (independent of water pressure conditions), the total soap usage per washing is 2.0 ml.

b. <u>Laboratory Knife Washing</u> - The automatic time cycle set-up for the handwashing activity could possibly be used for the utensil cleansing (based on average test data). However, most test subjects expressed the desire to not have this activity set-up on an automatic scale due to the fact that the time required to do the activity and waste usage depends greatly on the degree of dirtiness of the utensil (see Table III-9). For a relatively clean knife, the water usage per washing is approximately 95.3 ml or .095 kg (.21 lb). For a fairly dirty knife, this increases to 256.3 ml or .256 kg (.56 lb). Soap usage also increases for a dirty knife, 3.1 ml, compared to .97 ml for a clean utensil. Many test subjects express that the procedure set-up for the utensil cleansing should be changed in that the enclosure should be cleaned before the knife is dried, thus cutting down on water loss from the hands when removing the knife from the fixture. They felt some type of restraint should be supplied within the enclosure to hold the utensil while cleaning the enclosure, then the knife and hands should be dried in one operation. All tests were conducted at a water flow at 10.34×10^4 N/m^2 (15 psi). The spray pattern and water flow rate appeared adequate for cleansing small utensils.

c. <u>Personal Apparel Washing</u> - The total water used per washing of a T-shirt was 1387.1 ml and 1107.7 ml for the wool socks. When washing the clothes, fogging of the enclosure due to the article blocking air flow through the enclosure caused very poor visibility. Test subjects commented that due to this fact they could not tell when enough soap had been applied and when the article was clean. The bulkiness of the T-shirt made maneuverability within the enclosure to clean a particular part of the clothing nearly impossible. It was, therefore, concluded that due to the excessive time involved, water usage, soap usage and discomfort, that apparel washing in the present design of the cleansing fixture was infeasible.

d. Shaving and Cleaning Razor - The amount of water utilized for this task was 681.25 ml or .68 kg (1.5 lb) per shaving. On the average, 4.65 ml (.01 lb) of shaving cream was used. All the test subjects commented that they would have preferred to use a shaving cream of their choice over that which was provided. They also commented that shaving using the present set-up was relatively easy as long as they did not apply too much shaving cream to their hand. Therefore, from the test subject's comments and from the test data, shaving as was set-up seems a feasible activity for the cleansing fixture. Since every crewman has his own procedure for shaving, and the time of task varies from each crewman, an automatic control set-up for this activity is impractical.

e. Brushing Teeth - Total amount of water utilized for this task was on the average 143.75 ml or .144 kg (.32 lb) per washing. Baking soda was used for the performance of the task, however, several test subjects complained about the bad taste and said they would have preferred to use their own brand. All test subjects complained about the awkwardness of having to remove the enclosure dome to expectorate. Future designs will incorporate a hinged surface so that removal of the dome is facilitated. Except for this one item (which was inherent in the model used) the test subjects expressed no discomfort in using the fixture for brushing their teeth. All were able to basically follow their normal daily routine. Therefore, the cleansing fixture appears to be a feasible apparatus to be used for daily teeth brushing.

f. Wetting of Hair - The total amount of water used for this task was 68.75 ml or .069 kg (.15 lb). The test subject felt that wetting his hair using the prescribed procedure was fairly easy, however, he did not feel that it would be as easy to rinse his hair. Since the test was performed in a one "g" environment, water did not adhere to the test subject's hands as in zero "g" and subsequently water was lost when the hands were removed from the enclosure to wet the hair.

g. <u>Sponge-Type Body Wash</u> - The total amount of water utilized for this task was 250 ml or .25 kg (.55 lb). The task was relatively easy to do, however, it was not performed in the cleansing fixture; therefore, a water balance test could not be conducted. The above figure may vary somewhat from one obtained using the cleansing fixture since rinsing and wetting of the washcloth would be performed at the same time.

2. <u>Microbial Burden and Disinfection Studies</u>

a. <u>Microbial Burden</u> - The microbial burden on the interior surface of the hand cleansing unit varied from 0.65 to 8.02 microorganisms/sq cm (4.2 to 51.7 microorganisms/sq in) (olive leaf soap being used with the unit). These values are limited in a number of ways.

1) The swab does not pick up all microorganisms, and not all organisms grow on Trypticase Soy Agar or at 32°C aerobically.

2) Olive leaf soap is germicidal to <u>E. coli</u>, and, therefore, probably germicidal to other microbes. In one test, the population of <u>E. coli</u> was reduced 93.3% in 2400 seconds (forty minutes) after the soap solution was sprayed on seeded coupons.

3) There is a significant loss of viable organisms from desiccation over time. During tests conducted for this contract the hand cleansing unit was allowed to completely dry out for fairly long periods, something which would not happen during a period of normal use.

4) The assumption is made that microorganisms are uniformly distributed on the surface.

b. <u>Disinfection of Hand Cleansing Unit</u> - Wescodyne solution sprayed on interior surfaces and allowed to sit, reduced microbial burden from .65 microorganisms/sq cm (4.2 microorganisms/sq in) to .6 microorganisms/sq cm (3.9 microorganisms/sq in). These values are severely limited.

1) The initial burden was insufficient to allow meaningful interpretation of data.

2) It was difficult to spray the surfaces uniformly. An integral spray disinfection system is required.

3) Items 1, 2, 3 and 4 of a.

c. Disinfection Effectiveness of Olive Leaf, Wescodyne, and Sodium Meta-Bisulfite Solutions - (The following discussion will give rough estimates of the effectiveness.) Olive leaf reduced the population of *E. coli* on stainless steel coupons by 93.3% taking desiccation loss into account in 2400 seconds (forty minutes). Wescodyne reduced the population 100% in 3600 seconds (1 hour) and so did Sodium Meta-bisulfite. Application of this data to the hand cleansing unit is limited in these ways:

- Not all organisms would have the identified response *E. coli* does to Olive Leaf, Wescodyne, or Sodium Meta-bisulfite.
- Desiccation loss would be altered in normal use.

d. Die-Off from Desiccation - As Figure IV-8 shows, the initial burden of 3.1×10^3 microorganisms/sq cm (2.0×10^4 microorganisms/sq in) was reduced in 27900 sec (7 hrs 45 min) to 3.26×10^1 microorganisms/sq in (2.1×10^2 microorganisms/sq in), a decrease of 99% of the initial population. It must be remembered, however, that not all organisms have the same sensitivity to desiccation.

3. Water Balance - Taking into account moisture lost to ambient, moisture left in system atmosphere, water transferred to towel, and total water amount collected, the average amount of water that cannot be accounted for is 3 ml. The large amounts of water that could not be accounted for could possibly be due to:

- Water leakage
- Water remaining in crevices within the system
- Reaction time of both the test subject and recorder to timed sequence could be off
- Water nozzle might not flow at constant rate
- Different degrees of water present within the enclosure after cleaning

In several instances, for both these water balance test and those conducted during the test tasks, more water was collected than was theoretically delivered to the system. Reasons for this could be:

- Reaction time of both the test subject and recorder to timed sequence could be off
- Stagnant water within system could have been released
- Water nozzle might not flow at constant rate

Approximately 6.8 ml of water was lost to the ambient air for a constant 14 sec spray whereas for a handwashing activity consisting of a 4 sec pre-wet and 10 sec rinse (14 sec total), 5.78 ml of water was lost. Approximately .062 ml was left in the system atmosphere for the constant spray whereas .052 ml was left during a handwashing of the same total length. The differences in moisture amounts is due to the fact that during the handwashing, a 24 sec lapse occurred during the wet and rinse cycle.

4. Miscellaneous

a. Water Temperature - The average temperature that a person can stand for long periods of times is $320.40^{o}K$ ($117^{o}F$). Problems occurred during this test in that care had to be taken to not allow the water to gush from the nozzle, otherwise variations in temperature with the gushing resulted. Also it was difficult to establish the water at a particular temperature.

b. Soap Characteristics - Most test subjects felt that the soap used, Olive leaf, was very satisfactory. However, some did comment that they didn't care for the smell and it left their hands dry. It was noticed that if any small cuts were on the hands, the soap tended to sting them. During the utensil and clothes washing, the soap had very poor suds and it was found that it was difficult to remove the soap residue from the articles.

c. Maintenance - No maintenance was required of the system during the testing. The soap clogging occurred when the system is not in use for several weeks and was easily cleared. Since we were using a 25 ml buret for soap storage, it had to be filled after approximately 10 hand-washings, after 5 utensil cleansings and after every clothes washing.

5. Waste Chemical Fluid Disposal and Control of Evolved Gas - The amount of fluid vaporized into the air of the three chemicals tested for a 30-day mission is calculated as follows:

- Ethanol 6.87g per dump/.42 m^3 (15 cu ft) air
  6.87g per dump x 30 = 206.1g ethanol/12.7 m^3 (450 cu ft) air
- 1,4-Dioxane 6.50g per dump/.42 m^3 (15 cu ft) air
  6.50g x 30 = 195g 1,4-Dioxane/12.7 m^3 (450 cu ft) air
- Trichloroethane 16.88g per dump/.42 m^3 (15 cu ft) air
  16.88g x 30 = 506.4g Trichloroethane/12.7 m^3 (450 cu ft) air

Assuming the same absorption characteristics, (i.e., capacity to absorb 20% of its weight) the following amounts of charcoal would be required for a 30 day mission.

- Ethanol 206.1 = 20% charcoal weight
  Charcoal required E = 1030.5g
  E = experimental estimate
- 1,4-Dioxane 195.0 = 20%
  Charcoal required E = 975g
- Trichloroethane 506.4 = 20%
  Charcoal required = 2532g

The total amount of charcoal required for these three materials for a 30 day mission based on the experimental estimates is 4,537.5g charcoal or 10.0 lb. This is 17.5% of the amount that would be required if the theoretical maximum values for vaporized materials were used.

V. DESIGN REQUIREMENTS

A. FINAL SYSTEM DESIGN PARAMETERS

1. <u>System Component Specification</u> - The following requirements, which were utilized in the final design concept, were determined as a result of the feasibility tests and calculations conducted:

- The water pressure at the cleansing enclosure shall be 1.02×10^5 N/m^2 (15 psi)
- The water temperature at the enclosure shall be 320.4^{o}K (117^{o}F)
- The water nozzle flow rate shall be 11 ml/sec (.17 gpm)
- The waste water shall have a flow rate of 1.58×10^{-5} m^3/sec (.25 gpm)
- The blower shall have a flow rate of .007 m^3/sec (15 CFM) with a system pressure loss of 47 mm (1.85 inches) of water maximum
- A two-phase line from the enclosure outlet to the LGS shall be sized for a velocity greater than 1.22 m/sec (40 fps) to move the water
- The air outlet line shall have a flow rate of .0056 m^3/sec (12 CFM)
- The nitrogen gas needed to pressurize the soap distribution system shall be regulated to 6.89×10^4 N/m^2 (10 psi)
- The soap nozzle flow rate shall be .5 ml/sec (.008 gpm)
- The disinfectant nozzles shall have a flow rate of 22.7 m/sec (.36 gpm) each

2. <u>Waste Chemical Fluid Disposal and Control of Evolved Gases</u> - Since some of the waste fluids are toxic, their transfer to the cleansing fixture shall be in a sealed container. This sealed container shall be designed to allow manual fluid transfer and have a pouring goose-neck nozzle that can interface with the fixture's waste collection inlet drain. This would allow the waste fluid to be transferred directly into the waste collection system by the air drag. If the liquid was poured openly into

the enclosure, a small portion may have to be moved manually with a crewman's hands or other special hand tool toward the drain. This would not be compatible with the crewman's health.

Assuming waste chemicals are dumped once per day and that the .42 m^3 (15 ft^3) of purged air is saturated with the chemical vapors, the total weight of vaporized chemicals is 3.04 kg (6.72 lbs). For a 30 day mission, the total weight becomes 91.3 kg (201.6 lbs).

Since charcoal is assumed to absorb 20% of its weight in chemical vapors, the theoretical charcoal weight becomes:

$$\frac{3.04 \text{ kg}}{.20} = 15.2 \text{ kg (33.6 lbs) per day}$$

$$\frac{9.13 \text{ kg}}{.20} = 456.7 \text{ kg (1008 lbs) for 30 days}$$

Based on experimental dumping of chemical fluids in the feasibility handwashing fixture, the weight of chemical vapor is 17.5 percent by weight of the theoretical values. Therefore, the following values should be used for the charcoal weight requirement:

$$(.175)(15.2 \text{ kg}) = 2.7 \text{ kg (5.88 lbs) per day}$$

$$(.175)(456.7 \text{ kg}) = 79.9 \text{ kg (176.4 lbs) for 30 days}$$

3. Materials, Parts and Processes - All materials used for different components, parts and processes shall be investigated for compatibility with performance and environmental criteria. Manufacturing processes and associated materials used on off-the-shelf hardware shall also be investigated for spacecraft compatibility. All materials used shall be identified on a list as either metallic or non-metallic with material trade name, application on the equipment, part number, vendor, commercial designation, approximate weight and dimension of material in each item in accordance with MSC Specification D-NA-0002 and MSC Specification MSC-04693.

a. Metals - The principal considerations for metals shall be their mechanical properties and corrosion resistance properties. In addition, there are some metals and alloys that are unacceptable for usage in space vehicle systems while others are preferred.

1) Unacceptable Metals - The following metals and alloys are unacceptable in a utensil/hand cleansing flight unit:

Beryllium	Unalloyed beryllium shall not be used within the crew compartment. Alloys containing less than 4 percent beryllium are acceptable.
Cadmium	Cadmium plated materials and alloys containing more than 30 percent cadmium are unacceptable.
Brass and Zinc	Zinc plated materials and alloys containing more than 30 percent zinc are unacceptable.
Copper	Copper shall not be used in components in contact with an aqueous media.
Magnesium	Magnesium or any magnesium alloys are unacceptable.
Mercury	Unacceptable
Steel	Non-corrosion resistant steels (high carbon steels) are unacceptable

2) Preferred Metals for Spacecraft Application - Table V-1 identifies the preferred metals and alloys for usage on the utensil/hand cleansing structure, parts, components and assemblies. The preferred aluminum alloys shall be used for structure and the bladder tanks and the preferred corrosion resistant stainless steels shall be used for all fluid handing components.

3) Dissimilar Metals - The use of dissimilar metals in contact shall be avoided unless adequately protected against galvanic corrosion. Metals that differ in potential by more than 0.25 volts, determined from Table V-2 (MSC Standard No. 63), shall not be used in direct contact when exposed to a common electrolyte such as the atmosphere.

TABLE V-1. METAL STRUCTURAL MATERIAL CANDIDATES FOR FIXTURE DESIGN

MATERIAL	WEIGHT $kg/m^3 \times 10^4$ (lb/in^3)	FLEXIBLE STRENGTH $N/m^2 \times 10^6$ (1000 PSI)	TENSILE STRENGTH $N/m^2 \times 10^6$ (1000 PSI)	IMPACT STRENGTH m-kg/cm (FT-LB/IN)	MAX. SER TEMP ^oK (^oF)		
Aluminum 6061 T6	.27 (0.098)	-	310.3 (45)	-	422 (300)	Skin & Frame Details	Sections and panels fabricated to suit application - would require considerable detail work and assembly. A good finish would be required for corrosion protection. Heavy compared to laminates.
2024 T3	.277 (0.100)	-	482.7 (70)	-	463.7 (375)		
7075 T6	.28 (0.101)	-	572.3 (83)	-	394.3 (250)		
7075 T73	.28 (0.101	-	462 (67)	-	394.3 (250)		
Stainless Steel 304L	.8 (0.29)	-	558.5 (81)	6 (110)	1255.4 (1800)		Sections and panels fabricated to suit application. Would require considerable detail work and assembly. Good corrosion resistance. Weight is a problem.
321	.8 (0.29	-	586 (85)	6 (110)	1199.8 (1700)		
Titanium Ti-6-Al	.45 (0.162)	-	758.5 (110)	-	866.5 (1100)		As with the steel alloys, weight saving over steel but material is costly.

TABLE V-2. METAL COUPLES*

Group No.	Metallurgical Category	E.M.F. (Volt)	Permissible Couples
1	Gold, solid and plated; gold-	*0.15	
2	Rhodium, graphite	*0.05	
3	Silver, solid or plated; high silver alloys	0	
4	Nickel, solid or plated; monel metal, high nickel-copper alloys, titanium	-0.15	
5	Copper, solid or plated; low brasses or bronzes; silver solder; German silver; high copper-nickel alloys; nickel-chromium alloys; Austenitic stainless steels	-0.20	
6	Commercial yellow brasses bronzes	-0.25	
7	High brasses and bronzes; Naval brass; Muntz metal	-0.30	
8	18% chromium type corrosion-resistant steels	-0.35	
9	Chromium, plated; tin, plated; 12% chromium type corrosion-resistant steels	-0.45	
10	Tin-plate; terneplate; tin-lead solders	-0.50	
11	Lead, solid or plated; high lead alloys	-0.55	
12	Aluminum, wrought alloys of the Duralumin type	-0.60	
13	Iron, wrought, gray or malleable; plain carbon and low alloy steels, armco iron	-0.70	

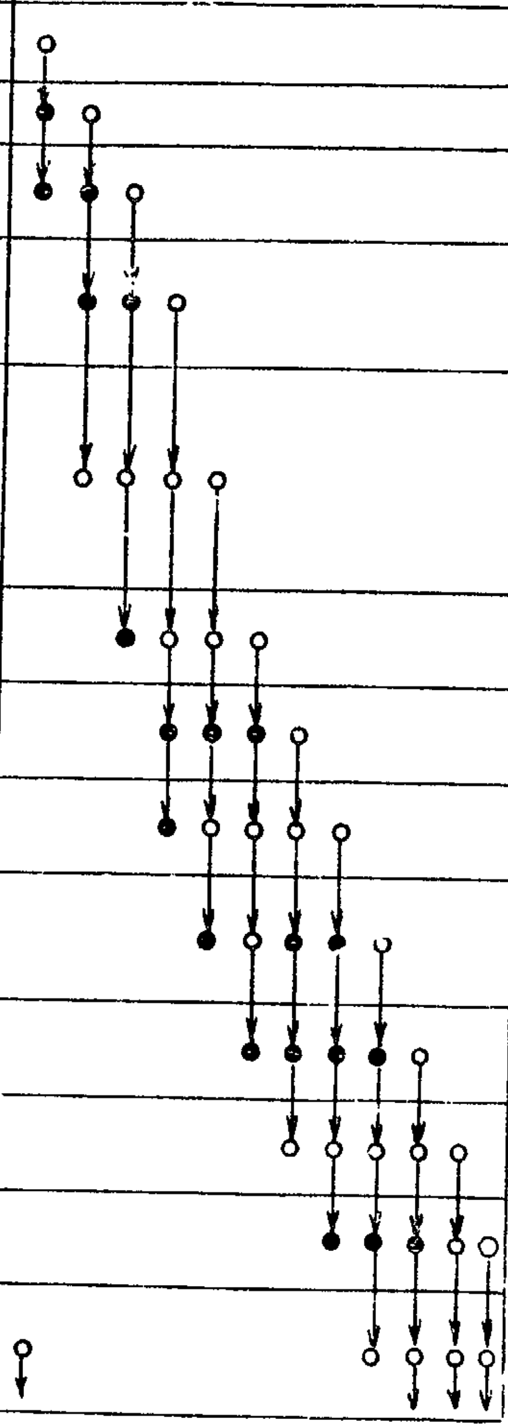
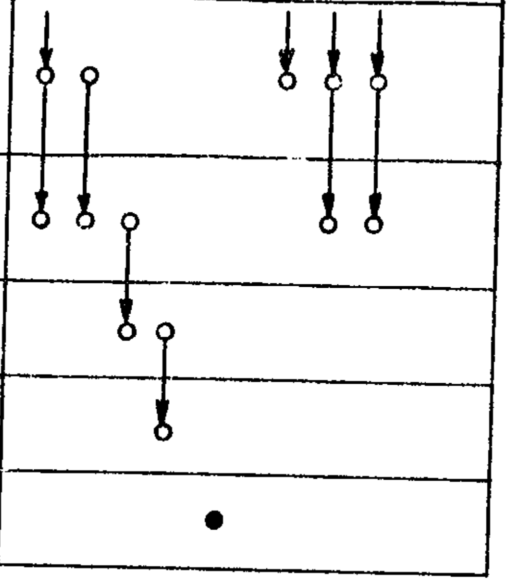


TABLE V-2. METAL COUPLES* (continued)

Group No.	Metallurgical Category	E.M.F. (Volts)	Permissible Couples
14	Aluminum, wrought alloys other than Duralumin type; aluminum, cast alloys of the silicon type	-0.75	
15	Aluminum, cast alloys other than silicon type; cadmium, plated and chromated	-0.80	
16	Hot-dip-zinc plate; Galvanized steel	-1.05	
17	Zinc, wrought; zinc-base die-casting alloys; zinc, plated	-1.10	
18	Magnesium and magnesium-base alloys cast or wrought 2/	-1.60	

1/ Members of groups connected by lines are considered to form permissible couples. These permissible couples should not be construed to be totally devoid of galvanic action, but rather to represent an acceptably low galvanic effect. O indicates the most cathodic member of the series, ● an anodic member, and the arrows the anodic direction.

2/ Aluminum alloys 5052, 5056, 5356, 6061, and 6063 are considered to form permissible couples with magnesium alloys.

* Reference: MSC Design and Procedure Standard Number 63, p. 2.

b. Non-Metallics - The principal considerations for non-metals shall be their mechanical properties and their resistance capabilities to flammability and off-gassing. A review of non-metallics considered for the utensil/hand cleansing fixture has shown different materials to be unacceptable for usage in space system application while others are preferred.

1) Unacceptable Non-Metallics - The following materials are unacceptable for usage of the cleansing fixture:

Polyvinyl chloride (PVC)	PVC shall not be used on manned spacecraft except under the following condition: PVC's surface temperature will not exceed 322.04°K (120°F) and pressure will not be less than 20.68×10^3 N/m^2 (3 psia).
Shatterable Material	Material which can shatter shall not be used in the crew compartment unless positive collection protection is provided.

2) Non-Metallics Considered for the Utensil/Hand Cleansing Fixture - Table V-3 identifies the non-metallic materials to be considered in the preliminary design of the cleansing fixture. This material list is prepared for information and for use in determining candidate materials appropriate for the utensil/hand cleansing fixture. The first choice of materials for the enclosure dome is polycarbonate due to high chemical resistance and can be easily worked and formed. The skin of the cabinet shall be constructed of a lightweight material.

4. Allocation of Performance Budgets

a. Water Usage and Balance - Water balance tests were conducted during each task. To facilitate the recording of data, wet and dry bulb temperature readings of the blower air were recorded when the system simulated a handwashing (the system was purged for 4 seconds to simulate a wet cycle, then purged again for 10 sec (rinse) 24 seconds

TABLE V-3. NON-METALLIC STRUCTURAL MATERIAL CANDIDATES FOR FIXTURE DESIGN

MATERIAL	WEIGHT kg/m^3x10^4 (lb/in^3)	FLEXIBLE STRENGTH N/m^2x10^6 (1000 PSI)	TENSILE STRENGTH N/m^2x10^6 (1000 PSI)	IMPACT STRENGTH m-kg/cm (FT-LB/IN)	MAX SER TEMP ^oK (^oF)		
Phenolic Glass Laminate	.18 (0.065	-	68.9 (10)	1.1 (20)	477.6 (400)	Skin Frame Details	Same as epoxy glass but not as strong and chemical resistance is poor. Might not meet flammability and/or outgassing reqmts.
Polyester Glass Fiber Laminate	.18 (0.065^T)	103.4 (15)	68.9 (10)	.27 (5)	477.6 (400)		Same as epoxy glass but not as strong. Fair chemical resistance. Might not meet flammability and/ or outgassing requirements.
Polyimide Glass Laminate	.188 (0.068)	386 (56)	1039.3 (150)	.93 (17)	699.82 (800)		Same as epoxy glass and nearly as strong. High temperature resistance. Would meet flammability and outgassing requirements. Cost might be a factor.
ABS High Impact	.102 (0.037	55.2 (8)	41.4 (6)	.44 (8)	366.5 (200)	Skin & Details	Molded or fabricated into details; easy to work with; fair chemical resistance; probably would not meet flammability requirements.
Acrylic	16.72 (6.041)	68.9 (10)	48.3 (7)	.082 (1.5)	3665 (200)		Same as ABS except material has poor resistance to organics.
Polycarbonate	.12 (0.043)	96.5 (14)	62 (9)	.544 (10)	366.5 (200)	Skin & Details	Stronger material than ABS. Good chemical resistance. Easily handed and worked. Expensive.

TABLE V-3. NON-METALLIC STRUCTURAL MATERIAL CANDIDATES FOR FIXTURE DESIGN (continued)

MATERIAL	WEIGHT kg/m^{3}x10^4 (lb/in^3)	FLEXIBLE STRENGTH N/m^{2}x10^6 (1000 PSI)	TENSILE STRENGTH N/m^{2}x10^6 (1000 PSI)	IMPACT STRENGTH m-kg/cm (FT-LB/IN)	MAX SER TEMP ^{o}K (^{o}F)		
Polyimide	.139 (0.050)	103.4 (15)	-	.054 (1)	533.2 (500)	Skin, Details, Frame	Very strong material as compared to most plastics. Machinable, good dim. stability. Excellent chemical resistance. May be compression molded, good flammability and outgassing characteristics. Expensive.
Epoxy Glass Laminate "High Strength" 36% Resin	.18 (0.[illegible]	1172 (170)	1103.2 (160)	3.3 (60) "Edge	422 (300)	Skin Frame Details	Laminated into any configuration. High strength/weight ratio. Cost involved in making molds. Would probably meet flammability requirement, but would require test. No special finish required. Material is easily repairable. Good chemical resistance.
Kydex	(.066)	(10200)	(6500)	(736)	(180)		Easily molded copolymer (Acrylic/PVC). Will not meet toxicity, off-gassing and flame requirements.

later, which allowed for soap and wash cycle). By use of a psychrometric chart $\Delta G/\#dA$ were obtained and plotted against time as in Figure IV-6 From this, an average value of $\Delta G/\#dA$ was found and the water loss to the ambient air through the blower was determined. The water left in the system atmosphere can be determined from the end point of Figure IV-6 at 120 sec.

Table V-4 summarizes the total water usage for each of the following activities: handwashing, laboratory utensil cleansing, shaving and cleaning razor, brushing teeth, wetting hair, and a "sponge-type" body wash. Also the total amount of water that was unaccounted for after considering water loss to the system atmosphere and to the ambient is given.

TABLE V-4. SUMMARY OF WATER USAGE AND BALANCE

	Total Water Usage(ml)	Water Transferred to Towel	Water Lost to Ambient (ml)	Water Left in System Environ. (ml)	Total Unaccounted Water (ml)
Handwashing	182.6	2.2	6.85	.062	18.5
Utensil Cleansing	134.2	1.84	5.4	.045	15.6
Shaving	681.25	4.3	22.5	.20	2.35
Brushing Teeth	143.75	.85	4.75	.043	- 5.6
Hair Wetting	68.75	6	2.3	.02	14.43
Body Wash	250*	-	-	-	-

* Water Balance not performed

To find the total water usage per day, assume the following constraints:

- Ten handwashings/day/crewperson
- One utensil cleansing/day/crewperson
- Two body washes/week/crewperson

- Two brushing teeth/day/crewperson
- One shaving/day/crewperson
- Two hair wettings/week/crewperson

By use of the following formula, the total water usage for each activity was determined and is listed in Table V-5:

Total Water Usage: # crewman x # operations/day x water usage/activity

TABLE V-5 TOTAL WATER USAGE

ACTIVITY	WATER USAGE/DAY
Handwashing	1.28×10^4 ml (28 lbs)
Utensil Cleansing	1.83×10^3 ml (4 lbs)
Shaving	4.8×10^3 ml (10.6 lbs)
Brushing Teeth	2.02×10^3 ml (4.45 lbs)
Hair Wetting	1.4×10^2 ml (.31 lbs)
Body Wash	500.5 ml (1.1 lbs)

b. Power - A power budget timeline for the automatic handwashing sequence is shown in Figure V-1.

1) Blower Energy Requirement - The total blower power consumption/day equals the blower power (18 watts) multiplied by the operation time and the number of operations per day.

The blower must remain on during the entire handwashing sequence for water collection and visibility requirements. The average blower on time for each activity is as follows:

- Handwashing: 67 sec
- Utensil Cleansing: 63 sec
- Shaving: 287 sec
- Brushing Teeth: 163 sec
- Hair Wetting: 108 sec
- Body Wash: 120 sec

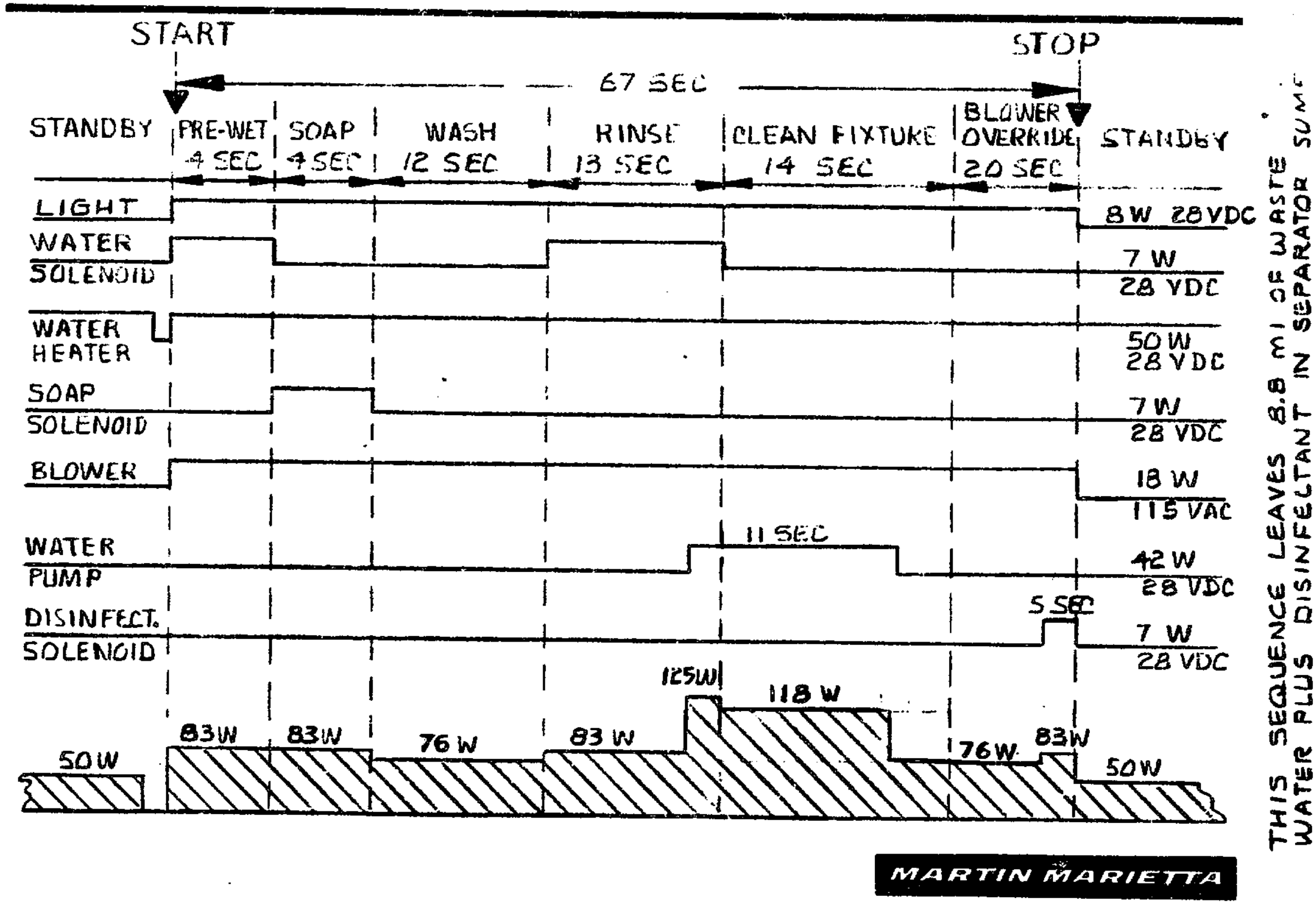


Figure V-1. Automatic Operation Time Sequence for 10.34×10^4 N/m^2 (15 psi)

Table V-6 summarizes the blower energy requirement for each of the above activities.

TABLE V-6 BLOWER ENERGY REQUIREMENT

ACTIVITY	JOULES/DAY (WATT-HRS/DAY)
Handwashing	8.44×10^4 (23.45)
Utensil Cleansing	7.94×10^3 (2.21)
Shaving	3.62×10^4 (10.05)
Brushing Teeth	4.11×10^4 (11.41)
Hair Wetting	3.89×10^3 (1.08)
Body Wash	4.32×10^3 (1.2)
TOTAL	177.85×10^3 (49.4)

2) Water Heater Energy Requirement - To find the total water heater energy requirement, the following formula and variables were used:

- $Q = MCp\ \Delta\ T$
- M = 22.06 kg (48.63 lb)
- $286^{o}K$ ($55^{o}F$) = temperature of ambient water
- $320.4^{o}K$ ($117^{o}F$) = temperature of water desired

From this then, the water heater energy requirement is 3.2×10^6 joules/day (884 watt-hrs/day) assuming zero heat loss to ambient.

3) Water Pump Energy Requirement - The total time the water pump is operating per washing for each activity is as follows:

- Handwashing: 11 secs
- Utensil Cleansing: 16 secs
- Shaving: 43 secs
- Brushing Teeth: 9 secs
- Hair Wetting: 4 secs
- Body Wash: 15 secs

Given that the water pump power is 42 watts, then the total water pump energy consumption is 5.7×10^4 joules/day (15.7 watt-hrs/day).

4) Water Solenoid Valve - The total time the water solenoid valve is open per washing fluid flowing is as follows:

- o Handwashing: 16.6 secs
- o Utensil Cleansing: 23.3 secs
- o Shaving: 61.93 secs
- o Brushing Teeth: 13.07 secs
- o Hair Wetting: 6.25 secs
- o Body Wash: 22.7 secs

The water solenoid valve has a power of 7 watts. Therefore, the total energy requirement of the solenoid valve 14×10^3 joules/day (3.9 watt-hrs/day).

5) Soap Solenoid Valve - The soap solenoid valve is in use only during the handwashing and utensil cleansing activity. The time the solenoid is open per washing (fluid flowing) is as follows:

- o Handwashing: 3.3 secs
- o Utensil Cleansing: 3.24 secs

The soap solenoid valve has a power of 7 watts. The total energy requirement is then 1.8×10^3 joules/day (.5 watt-hrs/day).

6) Light Assembly - The power of the fluorescent light fixture is 8 watts and is required to remain on during the same time period the blower is. The total energy requirement for the light is then 79.1×10^3 joules/day (22.03 watt-hrs/day).

c. Environment Impact

1) Towel Latent Penalty - Using the amount of water transferred to a towel during hand drying for each activity (Section IV) and the formula:

Towel Latent Penalty = Water transfer x heat of vaporization to towel

The towel latent penalty for each activity is summarized in Table V-7.

TABLE V-7 TOWEL LATENT PENALTY

ACTIVITY	JOULES/DAY (BTU/DAY)
Handwashing	441×10^3 (420)
Utensil Cleansing	29.4×10^3 (28)
Shaving	70.21×10^3 (66.5)
Brushing Teeth	29.4×10^3 (28)
Hair Wetting	27.5×10^3 (26)
Body Wash	12.6×10^3 (12)

2) Maximum Sensible Heat - The maximum sensible load per washing is calculated as follows:

Sensible Load = (usage) $M\Delta h$

- o Δh = 13.67 BTU/kg (6.2 BTU/lb) per MCR 75-347
- o Blower Blow Rate = 7.4×10^{-3} m^3/sec = 7.1×10^{-3} kg/sec (56 lbs/hr)

Table V-8 summarizes the maximum sensible heat for each activity.

TABLE V-8 MAXIMUM SENSIBLE HEAT

ACTIVITY	JOULES/DAY (BTU/DAY)
Handwashing	469×10^3 (455)
Utensil Cleansing	45.22×10^3 (42.7)
Shaving	20.58×10^4 (194.6)
Brushing Teeth	233.8×10^3 (221.2)
Hair Wetting	22.022×10^3 (21.02)
Body Wash	28.73×10^3 (27.23)
TOTAL	1004.6×10^3 (961.75)

3) Maximum Latent Load - To find the maximum latent load per washing, the following formula is used:

$$\text{Latent Load} = (\text{Usage})(\text{Mass})(\Delta\,\text{grains})\left(\frac{1\text{ lb}}{7000\text{ grains}}\right)(\text{heat of vaporization}).$$

ΔG is the average number of grains lost to the ambient air for the time period the blower is on. (Refer to Figure IV-6.) Table V-9 summarizes the total latent load for each activity.

TABLE V-9 LATENT LOAD

ACTIVITY	JOULES/DAY (BTU/DAY)
Handwashing	5.25×10^5 (497)
Utensil Cleansing	47.3×10^3 (44.8)
Shaving	2.25×10^5 (212.8)
Brushing Teeth	25.62×10^4 (242.2)
Hair Wetting	24.2×10^3 (23)
Body Wash	26.9×10^3 (25.5)
TOTAL	1.1×10^6 (1045.3)

d. Weight

1) Equivalent Weight - The total system penalties can be reduced to a common equivalent weight by knowing the payload penalties for power and heat load. These penalties are calculated based on the extra equipment necessary to accommodate the additional loads. Given the penalty equivalents in Table V-10, the equivalent weight impact per day to the spacecraft's system for each of the following conditions are summarized in Tables V-11 and V-12 respectively:

- o Ten handwashings, 1 utensil cleansing, 1 shaving, 2 brushing teeth, .286 hair wetting, .286 body wash per crewperson

- o Five handwashings, 1 utensil cleansing, 1 shaving, 2 brushing teeth, .286 hair wetting, .286 body wash per crewperson

TABLE V-10 EQUIVALENT WEIGHT PENALTIES

PENALTY TYPE	EQUIVALENT RATIO
Head added directly into cabin must be removed with cabin cooling circuit.	.198 kg/joule/sec (.128 lbs/BTU/hr)
Continuous DC Power	7.4×10^{-5} kg/joules (591 lbs/KW)
Continuous AC Power	8.95×10^{-5} kg/joules (710 lbs/KW)

TABLE V-11 EQUIVALENT WEIGHT IMPACT (10 Handwashings, 7 Utensil Cleansings, 7 Shavings, 14 Brushing Teeth, Hairwettings, and Body Wash Included)

PENALTY		EQUIVALENT WEIGHT
TOTAL WATER USAGE		22.06 kg (48.63 lb)
Blower Energy (AC):	177.85×10^3 joules/day (49.4 watt-hrs/day)	15.92 kg (35.07 lbs)
Water Heater Energy (DC):	3.2×10^6 joules/day (884 watt-hrs/day)	2.4×10^2 kg (522.4 lbs)
Light (AC):	49.38×10^4 joules/day (137.17 watt-hrs/day)	44.2 kg (97.4)
Water Pump Energy (DC):	5.7×10^4 joules/day (15.7 watt-hrs/day)	4.2 kg (9.3 lbs)
Water Solenoid Valve (DC):	14.3×10^3 joules/day (4 watt-hrs/day)	1.06 kg (2.4 lbs)
Soap Solenoid Valve (DC):	1.8×10^3 joules/day (.5 watt-hrs/day)	.133 kg (.3 lbs)
TOTAL JOULES/DAY (WATT-HRS/DAY): 3.38×10^6 (952.1)		
Towel Latent Penalty:	610.1×10^3 joules/day (580.5 BTU/day)	
Sensible Heat:	1004.6×10^3 joules/day (961.75 BTU/day)	
Latent Load:	1.1×10^6 joules/day (1045.3 BTU/day)	
TOTAL JOULES/DAY (BTU/DAY): 2.72×10^6 joules/day (2587.55 BTU/day)		6.2 kg (13.8 lb)
TOTAL EQUIVALENT WEIGHT DUE TO PENALTIES		333.76 kg (729.3 lb)

TABLE V-12 EQUIVALENT WEIGHT IMPACT (5 Handwashings, 7 Utensil Cleansings, 7 Shavings, 14 Brushing Teeth, Hairwettings, and Body Wash Included)

PENALTY		EQUIVALENT WEIGHT
TOTAL WATER USAGE		15.66 kg (34.46 lb)
Blower Energy (AC):	13.57×10^4 joules/day (37.675 watt-hrs/day)	12.15 kg (27.75 lb)
Water Heater Energy (DC):	2.3×10^6 joules/day (626.7 watt-hrs/day)	170.2 kg (370.4 lb)
Light (AC):	37.63×10^4 joules/day (104.6 watt-hrs/day)	33.68 (74.3)
Water Pump (DC):	4.04×10^4 joules/day (11.22 watt-hrs/day)	2.99 kg (6.63 lb)
Water Solenoid (DC):	9.93×10^3 joules/day (2.76 watt-hrs/day)	.73 kg (1.63 lb)
Soap Solenoid (DC):	97×10^3 joules/day (.27 watt-hrs/day)	.072 kg (.16 lb)
TOTAL JOULES/DAY (WATT-HRS/DAY): 2.55×10^6 (695.445)		
Towel Latent Penalty:	389.61×10^3 joules/day (370.5 BTU/day)	
Sensible Heat:	770.1×10^3 joules/day (707.02 BTU/day)	
Latent Load:	842.1×10^3 joules/day (796.82 BTU/day)	
TOTAL JOULES/DAY (BTU/DAY): 2001.81×10^3 (1874.34)		4.6 kg (10 lb)
TOTAL		240.08 kg (525.33 lb)

2) Total Weight - Table V-13 is a weight estimate for the total system. The total weight is then the sum of the equivalent weight plus the component weight. The total weight, therefore, for the utensil/hand cleansing fixture is 385.86 kg (844.12 lb) for the ten handwashings and the other activities. If the number of usages for shaving, brushing teeth, body wash, hair wetting and utensil cleansing remain the same and the number of handwashings reduces to five, the total weight impact upon the spacecraft is 292.18 kg (640.15 lb). Figure V-2 is a plot of the weight that each activity adds to the total weight of the system. The dashed line represents the constant component weight that is added to each increment of equivalent weight.

e. Volume

1) Space Rack - The volume of a single space lab rack is .73 m^3 (25.77 ft^3). The volume of the rack is utilized from the floor to a height of 1.77 m (70 in).

2) System - The volume each system utilizes is summarized below:

Water Distribution System: 4502 cm^3 (274 in^3)
Soap Distribution System: 5080 cm^3 (310 in^3)
Microbiological Control System: 2065 cm^3 (126 in^3)
Pressurant System: 923 cm^3 (56.3 in^3)
Air Distribution System: 9299 cm^3 (567 in^3)
Waste Water System: 26374 cm^3 (1608 in^3)
Electrical Subsystem: 6133 cm^3 (374 in^3)
Total Volume Utilized: 54376 cm^3 (3315.3 in^3)

B. SYSTEM DESIGN DETAIL

1. Structures

a. Mechanical - Figure V-3 shows the mechanical schematics of the Utensil/hand cleansing fixture. Potable water shall enter the system through a positive isolation disconnect at the coupling interface. The water shall then be heated to the desired temperature in the hot water holding tank. When the foot water control switch is activated, the solenoid

TABLE V-13 COMPONENT ESTIMATE WEIGHT

HARDWARE DESCRIPTION	UNIT Wt Kg (lb)	QTY	TOTAL Wt Kg (lb)
WATER DISTRIBUTION SYSTEM:			
Positive Isolation Disconnect	.57 (1.28)	1	.57 (1.28)
Hot Water Holding Tank	1.23 (2.7)	1	1.23 (2.7)
Water Heater Element	.4 (.88)	1	.4 (.88)
Water Heater Thermostat	2.27 (5.0)	1	2.27 (5.0)
Water Metering Valve	.34 (.75)	1	.34 (.75)
Solenoid Valve	.14 (.3125)	1	.14 (.3125)
Back Contamination Device	.22 (.5)	1	.22 (.5)
Water Nozzle	.07 (.156)	1	.07 (.156)
Drinking Water Dispenser	.45 (1.0)	1	.45 (1.0)
Tubing	.0635 (.14)	1	.0635 (.14)
Fittings and Coupling Nuts	.0454 (.1)	14	.6356 (1.4)
Flexible Tube	.054 (.12)	1	.054 (.12)
SOAP DISTRIBUTION SYSTEM:			
Soap Bladder Tank	1 (2.2)	1	1 (2.2)
Solenoid Valve	.14 (.3125)	1	.14 (.3125)
Flow Nozzle	.0363 (.08)	1	.0363 (.08)
Tubing	.141 (.31)	1	.141 (.31)
Fittings and Coupling Nuts	.0454 (.1)	4	.182 (.4)
Flexible Tube	.0454 (.1)	1	.0454 (.1)

TABLE V-13 COMPONENT ESTIMATE WEIGHT (Cont'd)

HARDWARE DESCRIPTION	UNIT Wt Kg (lb)	QTY	TOTAL Wt Kg (lb)
MICROBIOLOGICAL CONTROL SYSTEM:			
Disinfectant Bladder Tank	.55 (1.22)	1	.55 (1.22)
Solenoid Valve	.14 (.3125)	1	.14 (.3125)
Disinfectant Nozzle	.07 (.156)	3	.21 (.468)
Tubing	.141 (.31)	1	.141 (.31)
Fitting and Coupling Nuts	.0454 (.1)	6	.272 (.6)
PRESSURANT SYSTEM:			
Positive Isolation Disconnect	.57 (1.28)	1	.57 (1.28)
Pressure Regulator	.5 (1.1)	1	.5 (1.1)
Isolation Valve	.34 (.75)	3	1.02 (2.25)
Tubing	.49 (1.09)	1	.49 (1.09)
Fitting and Coupling Nuts	.0454 (.1)	13	.59 (1.3)
AIR DISTRIBUTION SYSTEM:			
Liquid-Gas Separator	2.25 (5)	1	2.25 (5)
Blower	.11 (.25)	1	.11 (.25)
Charcoal Filter	1.67 (3.7)	1	1.67 (3.7)
Tubing	.49 (1.09)	1	.49 (1.09)
Fitting and Coupling Nuts	.0454 (.1)	6	.272 (.6)

TABLE V-13 COMPONENT ESTIMATE WEIGHT (Cont'd)

HARDWARE DESCRIPTION	UNIT Wt Kg (lb)	QTY	TOTAL Wt Kg (lb)
WASTE WATER SYSTEM:			
Maintainable Filter	.9 (2)	1	.9 (2)
Pump Positive Isolation Disconnect	.57 (1.28)	2	1.14 (2.56)
Water Pump	1.6 (3.5)	1	1.6 (3.5)
Waste Water Bladder Tank	2.6 (5.7)	1	2.6 (5.7)
Isolation Valve	.34 (.75)	3	1.02 (2.25)
Positive Isolation Disconnect	.57 (1.28)	1	.57 (1.28)
Two Phase Tubing	.113 (.25)	1	.113 (.25)
Tubing	.213 (.47)	1	.213 (.47)
Fittings and Coupling Nuts	.0454 (.1)	16	.726 (1.6)
STRUCTURAL SUBSYSTEM:	19.2 (42)	1	19.2 (42)
ELECTRICAL SUBSYSTEM:	6.75 (15)	1	6.75 (15)
TOTAL			52.1 (114.82)

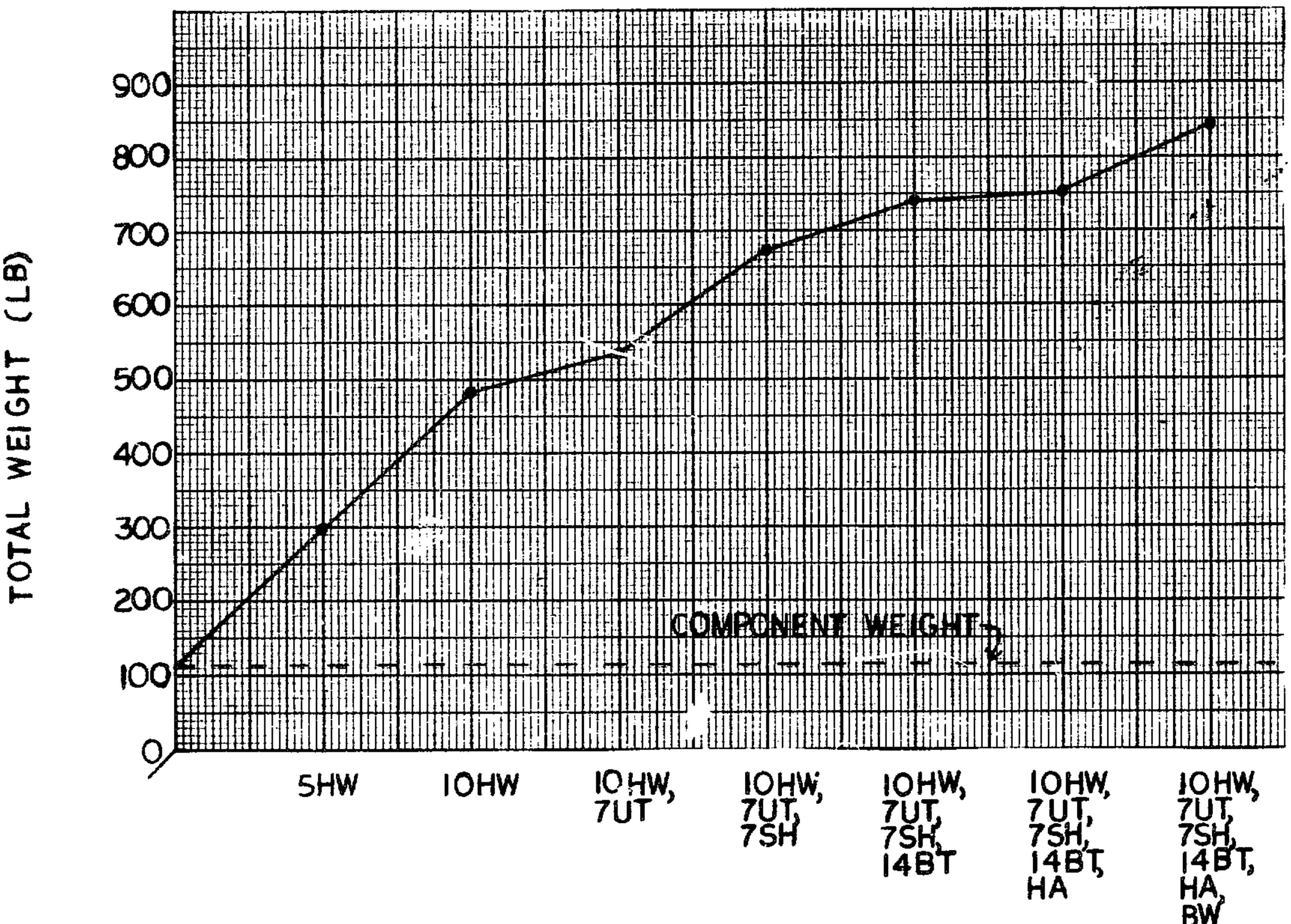
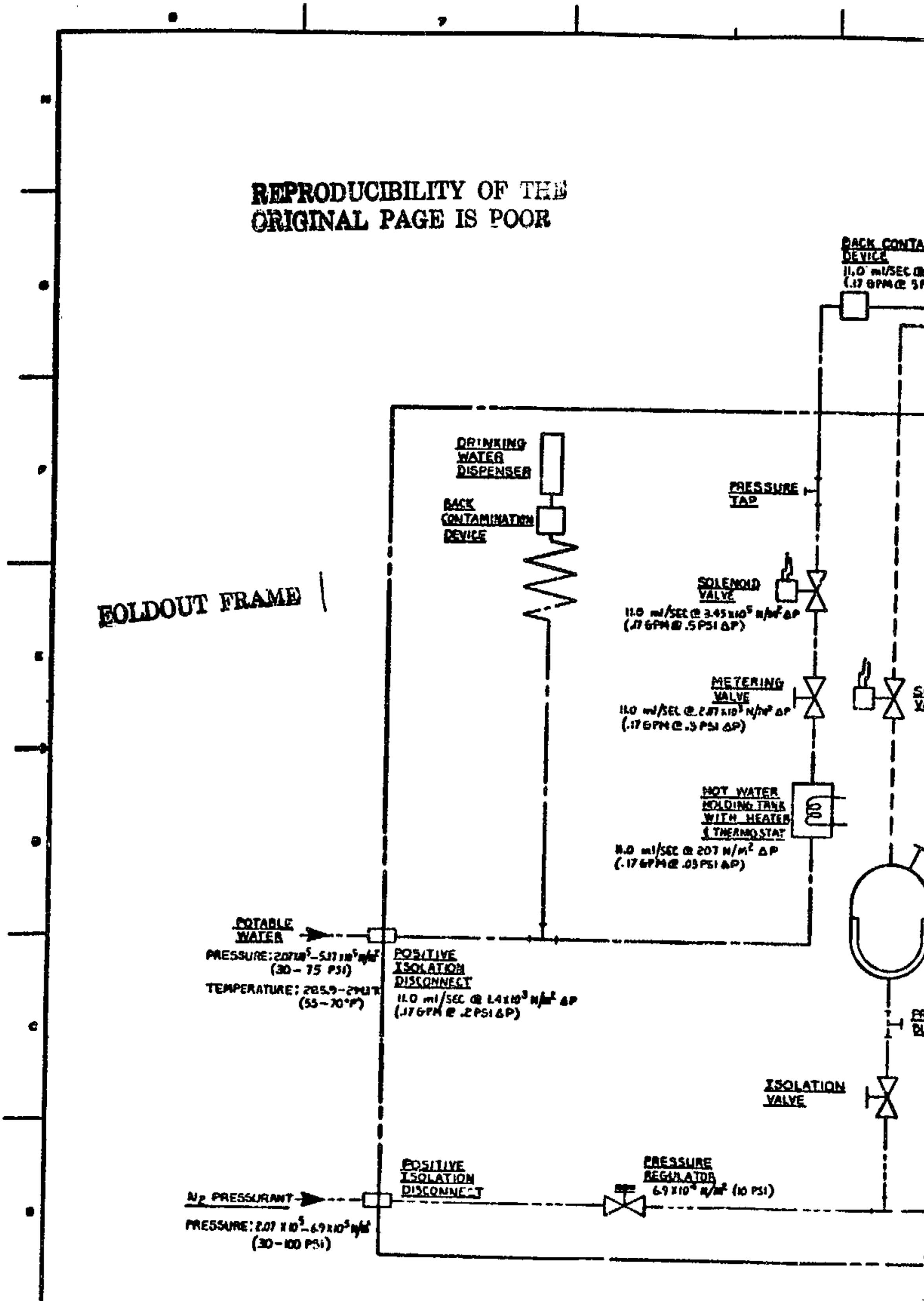
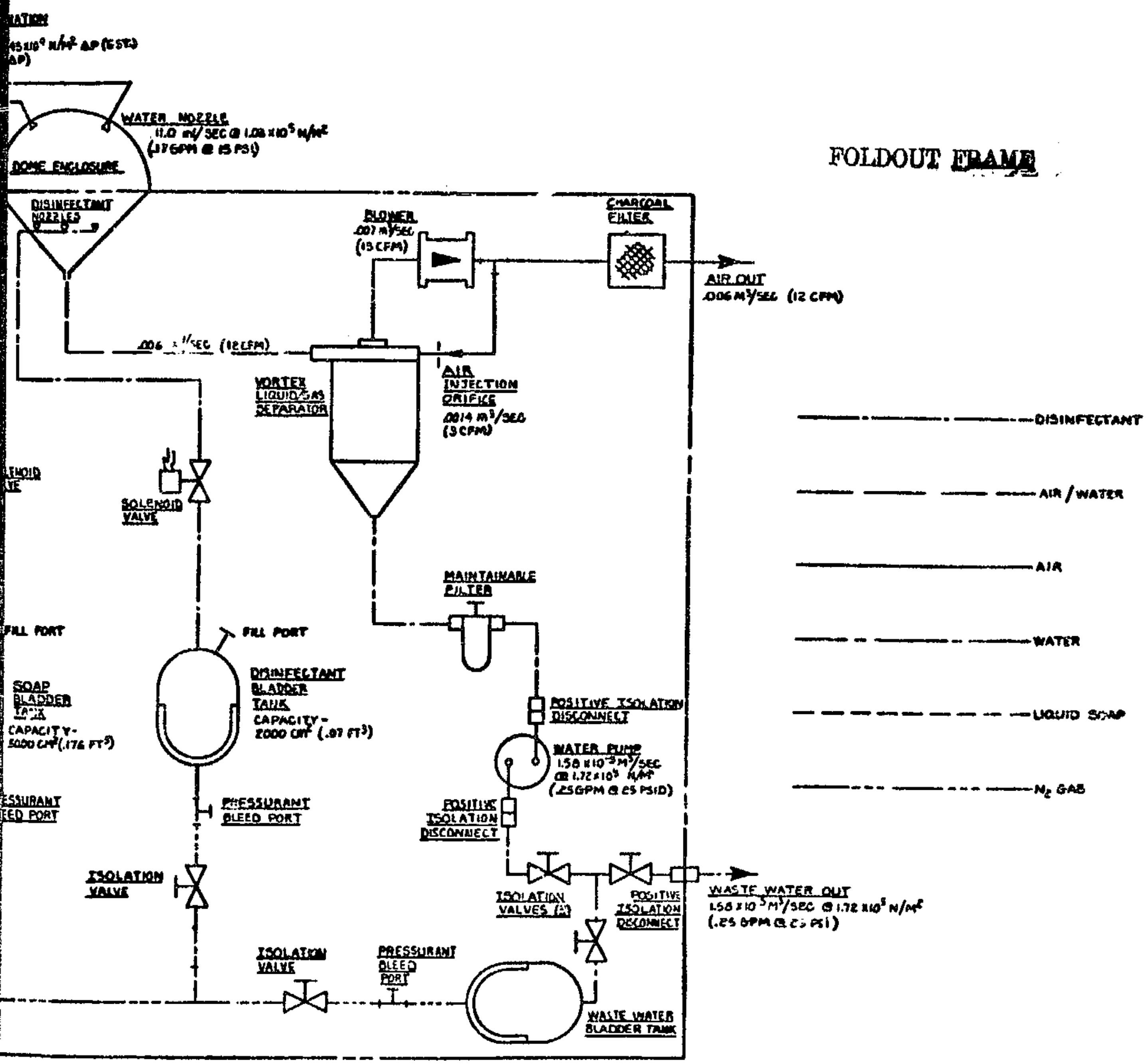


FIGURE V-2 TOTAL WEIGHT COMPARISON



.FIGURE V-3 MECHANICAL SCHEMATIC FOR UTENSI

FOLDOUT FRAME



/HAND CLEANSING FIXTURE

CLEANSING FIXTURE SYSTEM SCHEMATIC

valve opens and water shall be delivered to the enclosure through the provided nozzle. A metering valve shall be installed behind the solenoid valve so that the water flow rate can be adjusted. A back contamination device shall be incorporated so that bacteria shall be prevented in going back through the water supply system from the enclosure. A drinking water dispenser with a back contamination device will use water directly from the potable water line.

Soap shall be stored during the entire mission in the soap bladder tank. Nitrogen gas, which enters the system through the coupling interface, shall be used to provide a pressure behind the soap which, when the solenoid valve is open, will move up into the soap nozzle and flow into the enclosure. The same principle is used to deliver the disinfectant which shall also be stored in a bladder tank.

Water and soap mixed with air shall leave the enclosure through an opening in its basin and shall travel to the liquid-gas separator. The air shall be removed from the LGS by a blower and shall be transferred to the cabin ambient. The water shall collect in the sump of the LGS until it is full, at which time the water pump shall be activated and shall remove the water. The waste water shall either be delivered directly to the vehicle waste water line or shall be stored for emergency purposes in a waste water bladder tank within the cleansing system. Nitrogen gas shall be provided so that the waste water from this tank can eventually be moved to the vehicle waste water line.

b. <u>Electrical and Control</u> - Figure V-4 represents the electrical and control drawing for the cleansing fixture. A 115 VAC, 1Ø, 400 Hz power source and a 28 VDC power source shall be provided to the system at the coupling interface. A 5 volt control circuit that initiates from a power supply which changes the 28 VDC circuit to a 5 VDC shall activate the relays which control the electrical components in the cleansing fixture. The fluorescent light shall be activated manually by closing the light switch provided on the control panel. When the sequence mode switch is in the automatic position, a 5 VDC relay shall be activated for the blower, disinfectant solenoid, water pump, water solenoid and soap solenoid which

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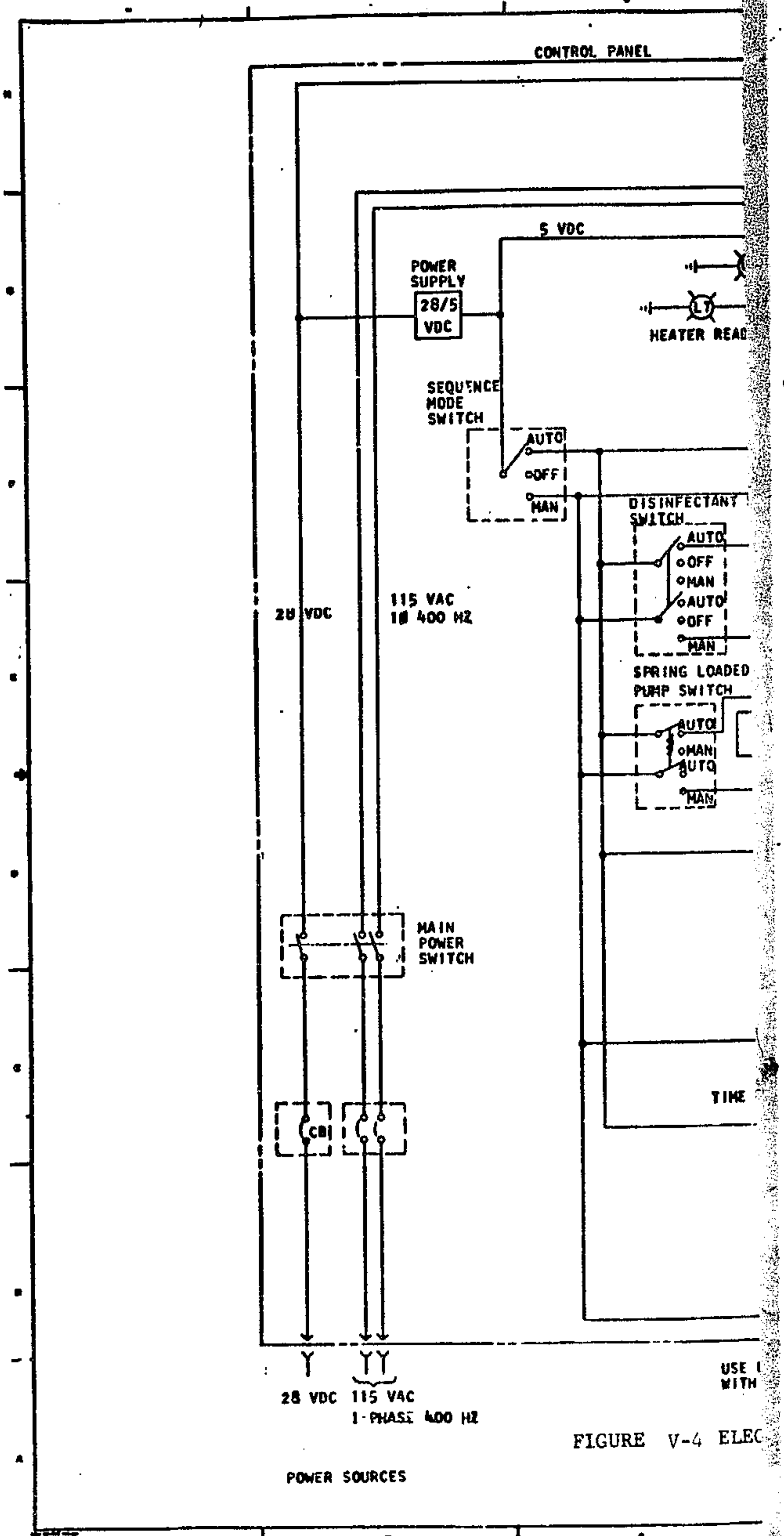
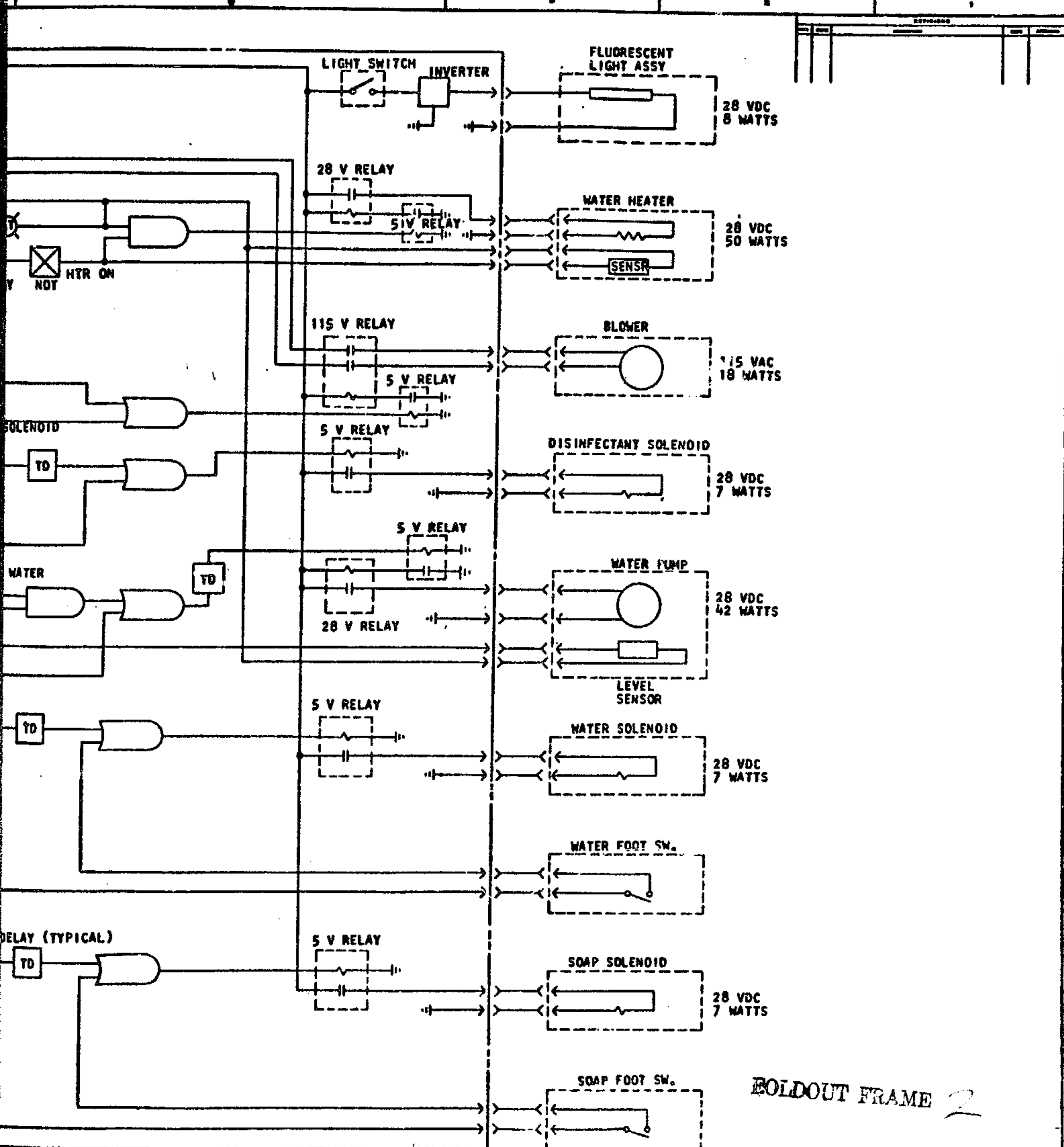


FIGURE V-4 ELEC

FOLDOUT FRAME



F FIVE VOLT DC LOGIC CIRCUITRY AND PRINTED CIRCUIT BOARD
INTEGRATED CIRCUIT HARDWARE

TRICAL AND CONTROL SCHEMATIC FOR UTENSIL/HANDCLEANSING FIXTURE closes contacts which allow the current to flow to these components. The blower shall be the only electrical component which operates using the 115 VAC. All other components shall be powered by the 28 VDC power source.

When the sequence mode switch is in the manual position, a 5 VDC relay shall activate the blower, disinfectant solenoid and water pump as before during automatic operation. However, to activate the soap and water solenoid, the appropriate foot switch shall be depressed which closes the circuit allowing activation of the 5 VDC relay. In turn, the soap and water solenoid are then operable. The automatic sequence is applicable to the handwashing activity only.

2. Top Assembly and Packaging - Packaging of the components of the cleansing fixture would need to take into account the neutral body position in zero-gravity of a crewperson.

Investigation into the utensil/hand cleansing fixture cabinet dimensions was initiated for a zero-gravity man interface based upon NASA document JSC-09551, "Neutral Body Posture in Zero-G", MIL-STD-1472 and AMRL-TR-70-5. The dimensions of the cabinet were selected to fit a 5th percentile female to a 95th percentile male. Using these dimensions, the final enclosure cabinet design has the dimensions as shown in Figure V-5 The design was selected so as to allow as little body movement for both extreme body dimensions as possible.

Figure V-6 shows the upper portion of the fixture cabinet and the eyes level of both the 95th percentile male and the 5th percentile female. For both the 95th percentile male and the 5th percentile female, the control panel is located very near their line of sight, therefore, the lights and switches are easily noted. It was determined from Figure V-6 that a mirror which pivoted from the top would be desirous so that each crewperson could adjust it to their own visual preference since the crew height varied to a great extent.

The width of the overall cabinet is such that it will fit within a spacelab rack 572 mm (22.52") in width. All valves and filters are located toward the front of the cabinet for easy maintenance. The front panel below the enclosure is removable as is a panel behind the

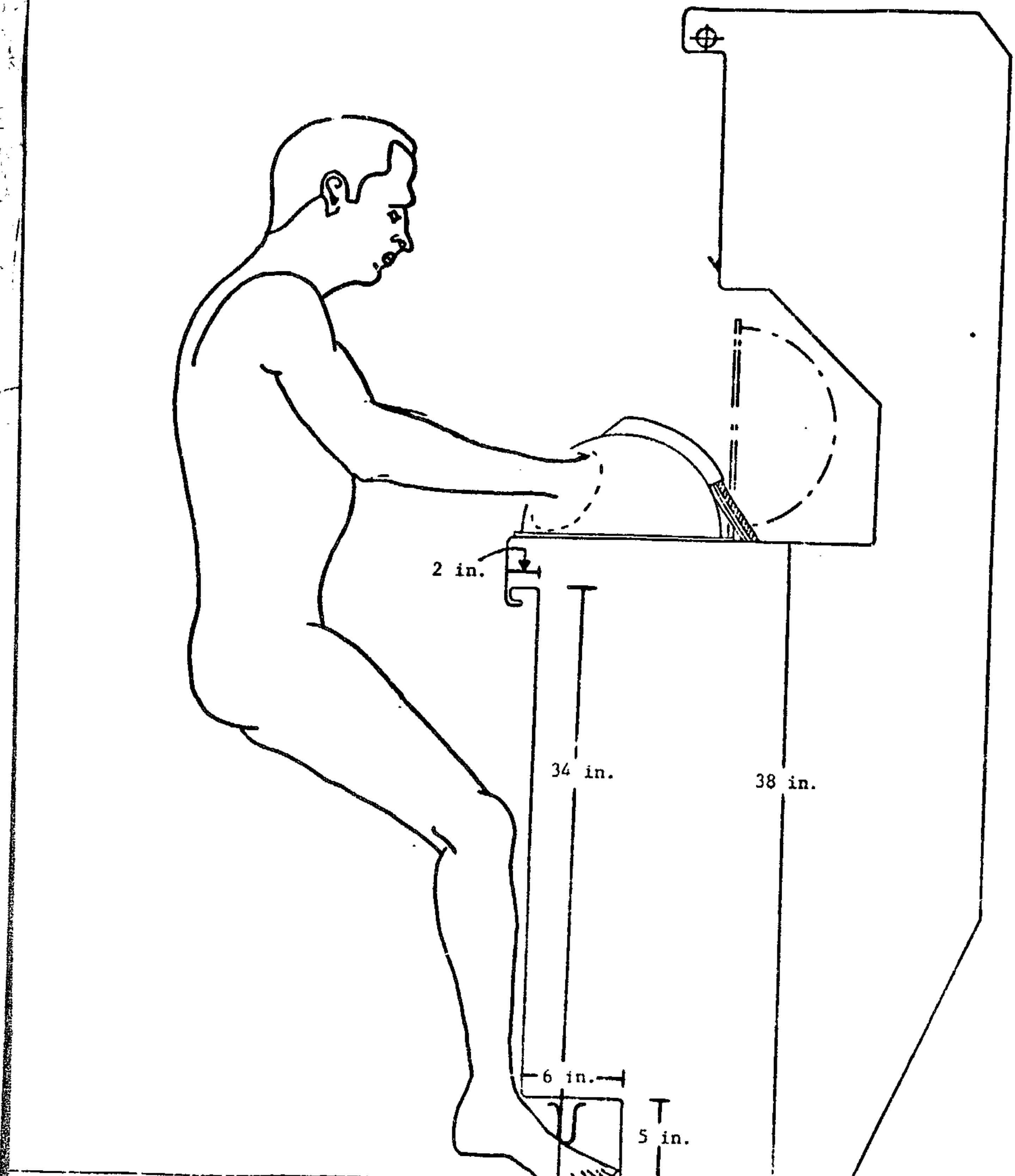


FIGURE V-5 ZERO-GRAVITY MAN-MACHINE INTERFACE

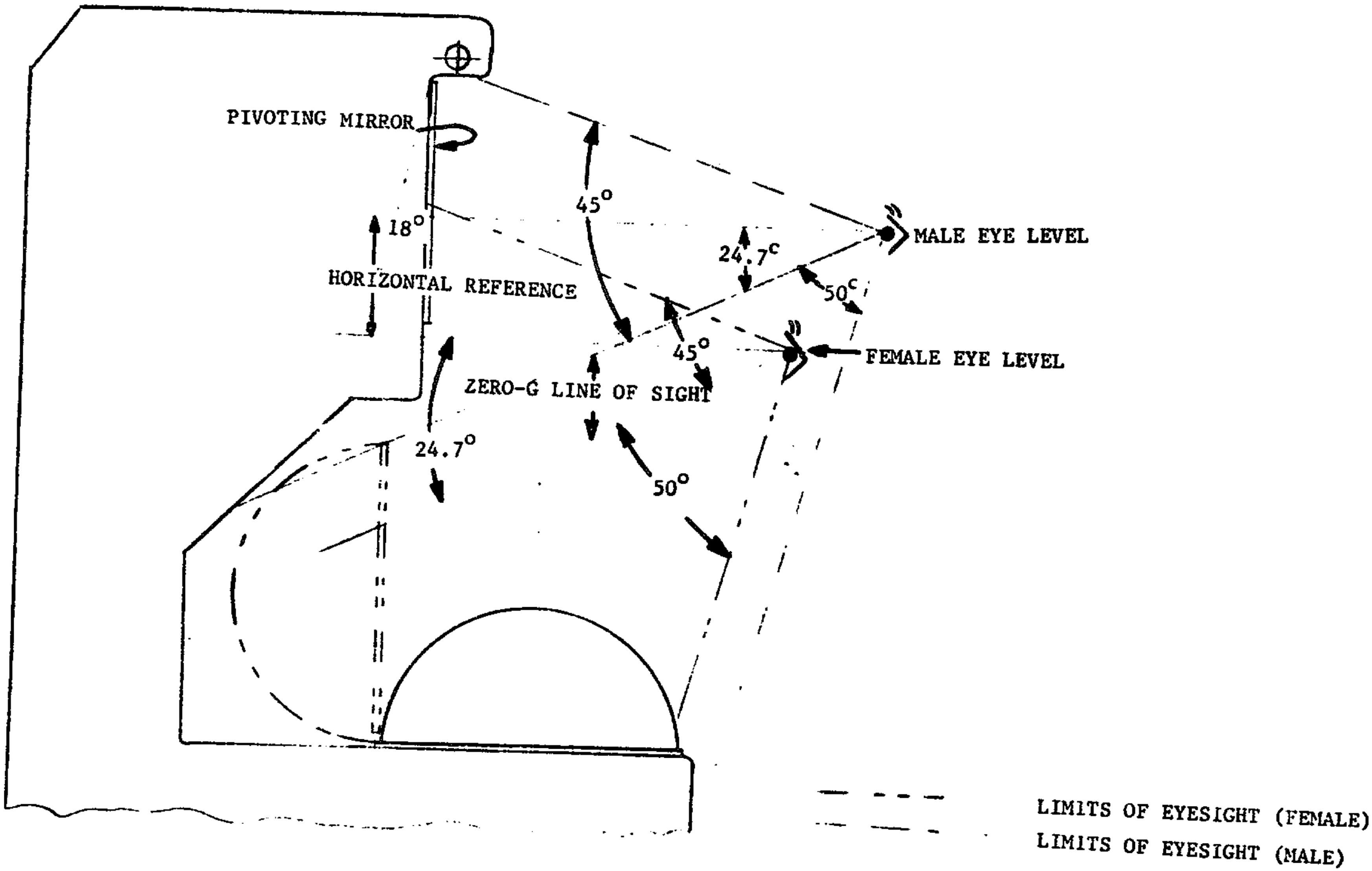


FIGURE V-6 EYESIGHT LIMITATIONS

enclosure so that these units are easily reached. The hinged mirror can be opened toward the crewperson to provide access to the circuit breakers and electrical components.

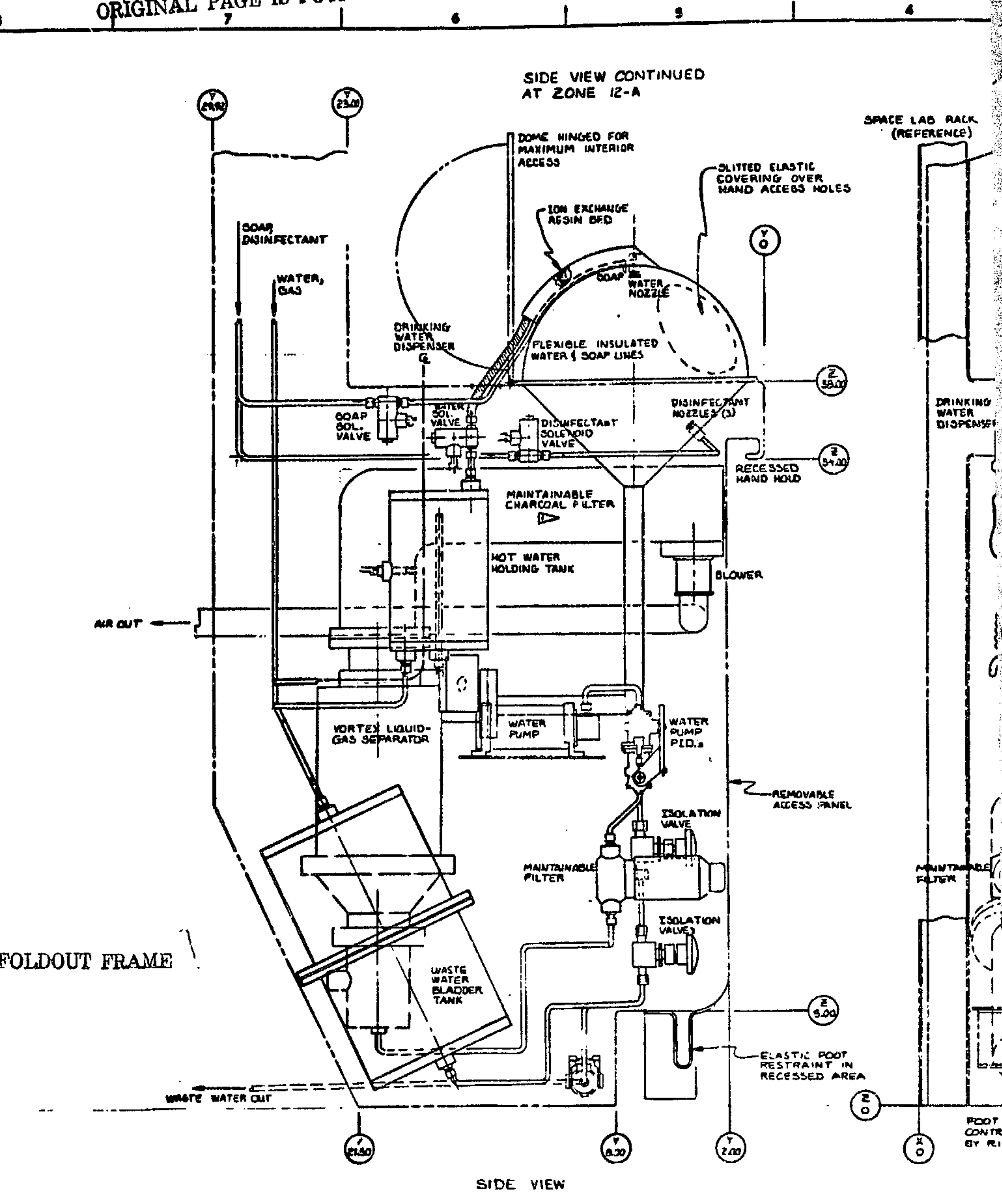
The upper portion of the cabinet was indented so that the light would illuminate the work area in the cleansing fixture. The mirror was indented beyond this point so that it also would be illuminated. Figure V-7 shows the final top assembly and packaging schematic which incorporates the above features for the utensil/hand cleansing fixture.

C. PERFORMANCE REQUIREMENTS

1. <u>Personnel Utilization</u> - The utensil/hand cleansing fixture shall be designed so as to accommodate both a 5th percentile female and a 95th percentile male in both a one- and zero-gravity environment. The functions that shall be capable of being performed in the fixture include handwashing, shaving, laboratory utensil cleansing, brushing teeth, hair wetting and body washing. The size of the individual components are designed so as to conform with the following usage constraints:

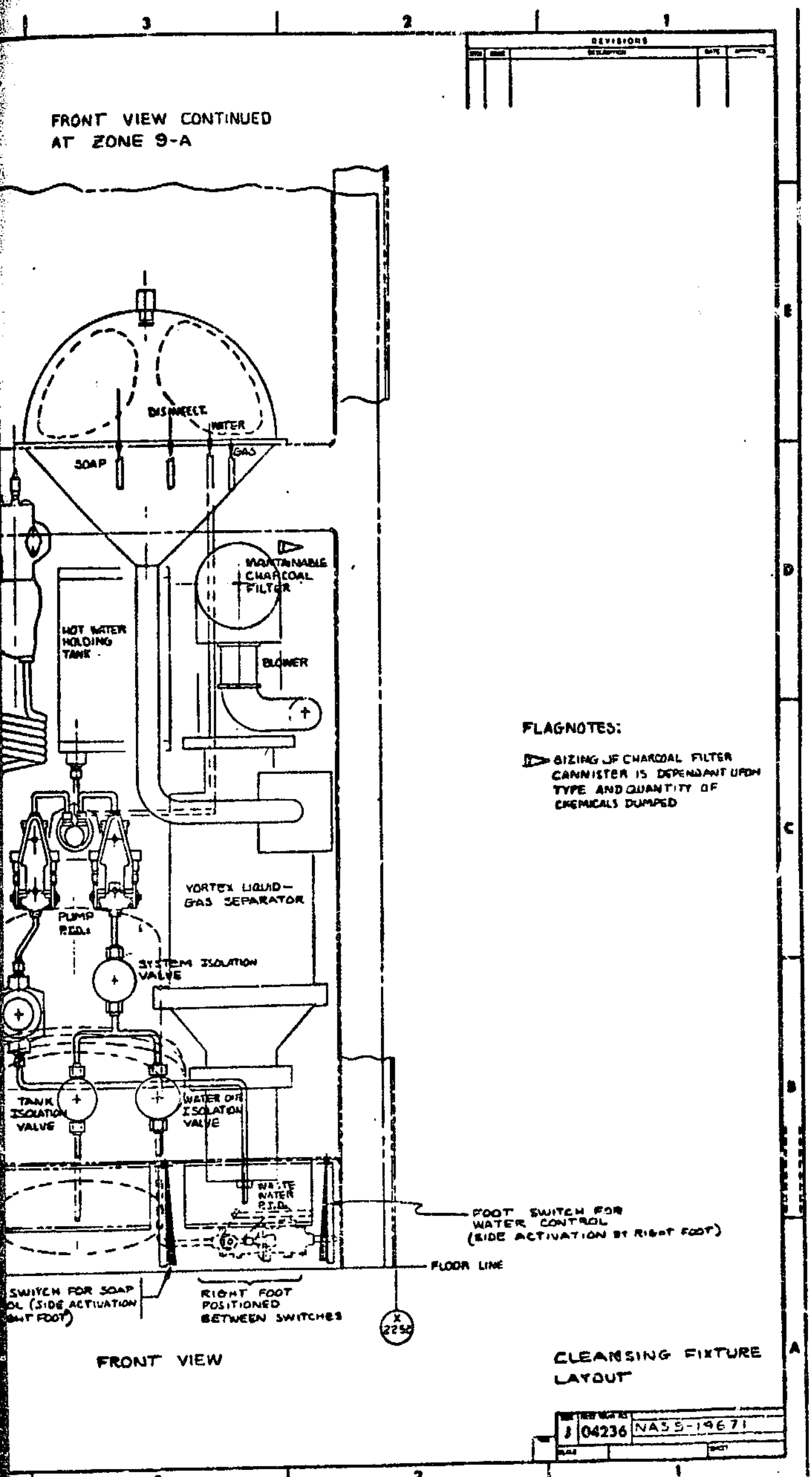
- o Maximum of 10 handwashings per day per crewperson
- o One utensil cleansing per day per crewperson
- o Two body washes per week per crewperson
- o Two teeth brushing activities per day per crewperson
- o One shaving per day per crewperson
- o Two hair wetting activities per week per crewperson

A hot water holding tank sized for 2.27 kg (5 pounds) with a 50 watt heating element shall have the water temperature thermostatically controlled to 320.4°K (117°F). As hot water is withdrawn by demand, cold water at 286.3°K (55°F) will be added to the tank. The heating element will be activated when water temperature drops below 320.4°K (117°F). Table V-14 tabulates water temperature in the holding tank as water is withdrawn for a handwashing.



FOLDOUT FRAME

FIGURE V-7 TOP ASSEMBLY AND PACKAGING SCHEMATIC



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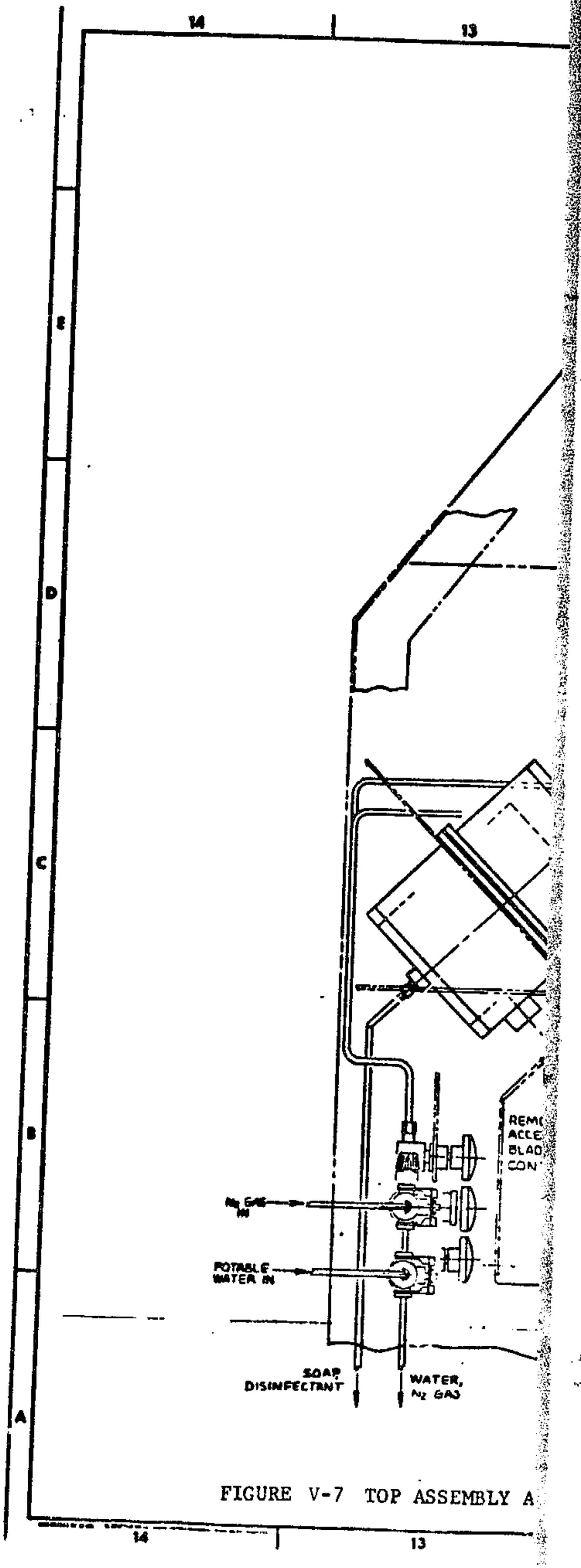
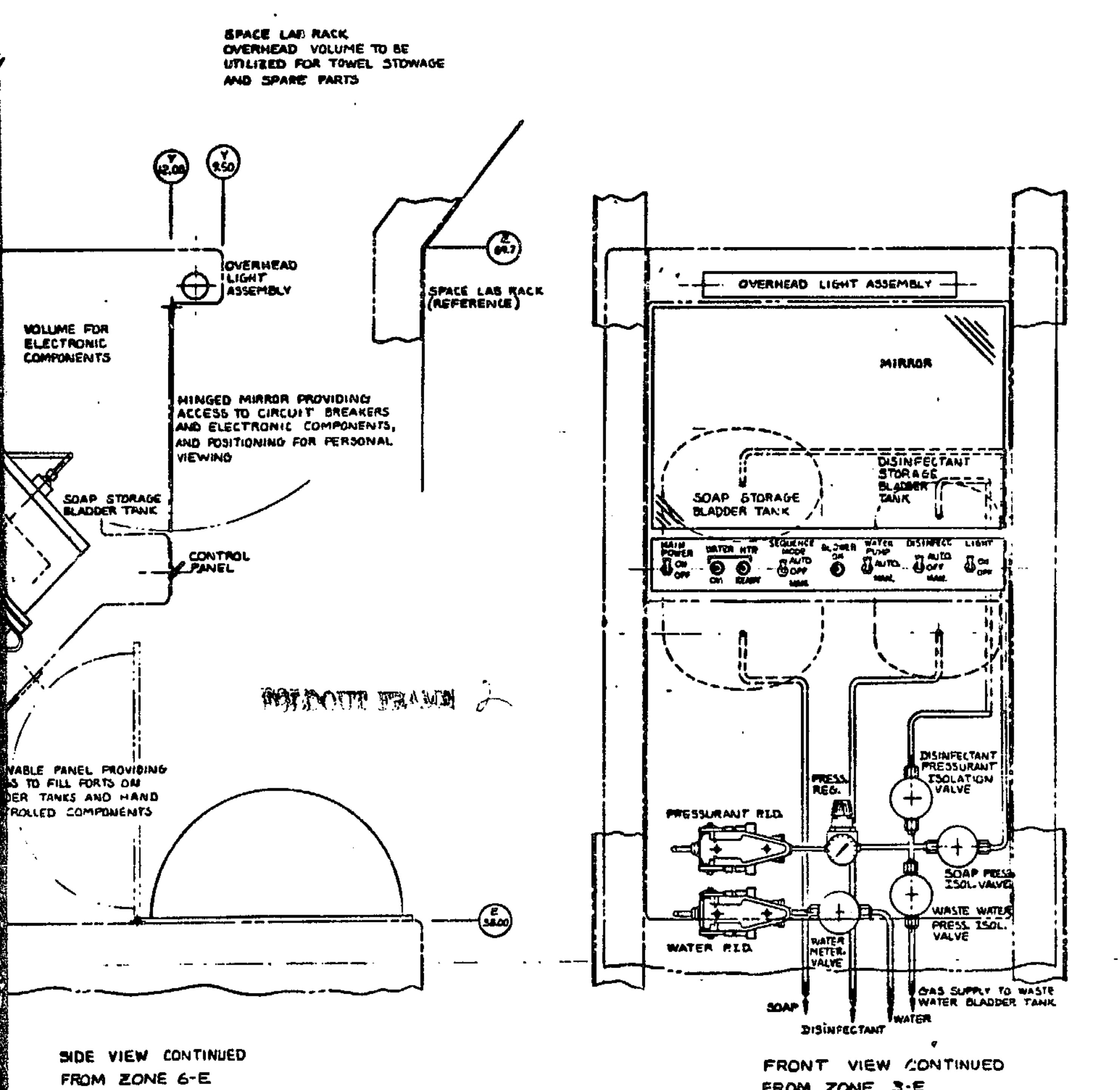


FIGURE V-7 TOP ASSEMBLY A

12 11 10 9



ND PACKAGING SCHEMATIC (Cont'd)

12 11 10 9

TABLE V-14 WATER TEMPERATURE AFTER ONE (1) WASHING

TIME (MIN)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Increase in Temperature Due to Heat Input (^{o}F)	0	+.57	+.57	+.57	+.57	+.57	+.57	+.57	+.57	0	0	0	0	0	0	0
Temperature Loss Due to Cold-Hot Water Mixing (^{o}F)	0	-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Net Change in Temperature (^{o}F)	0	-4.43	+.57	+.57	+.57	+.57	+.57	+.57	+.57	0	0	0	0	0	0	0
Temperature in Water Tank (^{o}F)	117	112.57	113.14	113.71	114.28	114.85	115.42	115.99	116.56	117	117	117	117	117	117	117
Handwashing	X															

Table V-14 shows that nine (9) minutes after the handwashing, the temperature in the holding tank has recovered 100 percent. To determine the shortest time that seven (7) handwashings could take place and still be within the water temperature comfort range, Table V-15 was tabulated. The effect of one (1) handwashing at five (5) minute intervals was calculated.

Table V-15 shows that seven (7) handwashings can be completed in 1800 seconds (30 minutes) with the water temperature still above the 314.1°K (105°F) minimum. An additional 1230 seconds (20.5 minutes) will be required after the last handwashing for the water temperature to again reach 320.4°K (117°F).

2. Operation - Table V-16 summarizes the operations sequence for both the automatic and manual mode for the unit.

3. Maintenance - Components which require routine maintenance shall be located in easily accessible areas in the cleansing unit. These items include the charcoal filter and the water line filter. Those items which require operational maintenance shall also be located in easily accessible areas which are on the front side of the cleansing unit. These components include the pressure regulator and water metering valve. Isolation valves shall be located for ease of operation in periods of refilling the soap and disinfectant storage tanks. Positive isolation disconnects shall be located on either side of the water pump since this item has a high replacement possibility.

In order to identify all potential subsystem failure symptoms, a preliminary mode and effect analysis was prepared. (See Table V-17)

The failure mode and effect analysis was completed to the predetermined repair level, which on the cleansing fixture is on the component replacement level. The analysis identifies all the component failure modes and their corresponding effects on the subsystem performance.

Welded connections and structure were considered to have a negligible frequency and were not considered as a possible failure mode in the FMEA. Each failure mode was categorized according to failure criticality.

TABLE V-15 WATER TEMPERATURE AFTER SEVEN (7) WASHINGS

TIME (MIN)	0	5	10	15	20	25	30	35	55.5
Increase in Temperature Due to Heat Input (^{o}F)	0	+2.85	+2.85	+2.85	+2.85	+2.85	+2.85	+2.85	+11.7
Temperature Loss Due to Cold-Hot Water Mixing (^{o}F)	0	-5	-4.79	-4.63	-4.49	-4.36	-4.24	-4.13	0
Net Change in Temperature (^{o}F)	0	-2.15	-1.93	-1.78	-1.64	-1.51	-1.39	-1.28	+11.7
Temperature in Water Tank (^{o}F)	117	114.85	112.91	111.13	109.49	107.98	106.59	105.3	117
Handwashing	X	X	X	X	X	X	X		

TABLE V-16 OPERATIONS SEQUENCE

AUTOMATIC MODE (Handwashing Activity Only)

1. Turn Main Power Switch to "ON" position
   - o Sequence mode switch should be in "OFF" position
   - o Pump switch should be in "AUTO" position
   - o Indicator light illuminates on operator's control panel to show water heater is "ON"
   - o Two hours required to raise water temperature from 286.3°K (55°F) to 321.4°K (118°F)
   - o When water temperature reaches 321.4°K (118°F), indicator light on operator's control panel illuminates to show that the cleansing fixture is ready for use

2. Turn on Overhead Light if Desired

3. Turn Sequence Mode Switch to "AUTO" Position
   - o Blower immediately starts and illuminates indicator light
   - o Automatic cycle begins
     - Pre-wet water sprays for 3.8 seconds
     - Soap dispenser sprays for 3.3 seconds
     - 11.8 seconds allowed to wash hands with soap
     - Rinse water sprays for 12.8 seconds
     - 13.7 seconds allowed for hand cleaning of fixture

   Pump automatically operates by level switch and is timed to run 11.0 seconds.
     - 30 seconds allowed to towel dry hands
     - Blower runs an additional 20 seconds to purge system

4. Turn off Overhead Light

   NOTE: If 5-second disinfectant spray is desired at end of automatic cycle, disinfectant switch must be placed in "AUTO" position before Step 3 above.

MANUAL MODE

1. Perform Step 1 and 2 of the Automatic Mode

2. Turn Sequence Mode Switch to "MANUAL" Position

Table V-16 Operations Sequence (cont)

- o Blower immediately starts illuminating indicator light
- o Any of the following operations can be performed manually at any time
  - Foot switch (not used in "AUTO" position) turns on water spray for pre-wet or rinse
  - Foot switch (not used in "AUTO" position) turns on soap spray
  - Water pump switch should be placed in "AUTO" position pump down automatically when LGS sump is full. Water pump switch will turn on water pump and pump out LGS sump until switch is turned off. Use for maintenance only.
  - Disinfectant switch in "MANUAL" position turns on disinfectant

3. Turn off Overhead Light

TABLE V-17 FAILU

OPERATIONAL SYSTEM	FAILURE MODE	RESULT ON SYSTEM	
WATER DISTRIBUTION SYSTEM			
o Positive Isolation Disconnect	o Face Seal Leakage	o Loss of Fluid	o Red
	o Clogged System	o Reduced Flow	o Fil
	o Poppet Closed	o No Fluid Flow	o Ope Est
	o Poppet Open	o No Fluid Flow Control	o Pro Rep
o Water Heater/Thermostat	o Power Discontinuity o Sensor Failure	o Ambient Water o No Temperature Control	o Pro Pro Rep
o Hot Water Holding Tank	o Ruptured Tank	o Loss of Water	o Bui
o Water Metering Valve	o Seal Leakage	o Undesirable Fluid Pressure at Nozzle	o Pro Pro Rep
o Solenoid Valve (Failed Closed)	o Power Discontinuity o Foot Switch Malfunction o Valve Stem Damage	o Flow Stoppage	o Man Pop
o Solenoid Valve (Fail Open)	o Valve Blockage (Structural or Seal Damage)	o No Fluid Flow Control	o Man Popp
o Lack Contamination Device	o Clogged, Reduced Efficiency	o Decrease Flow	o Fil
o Water Nozzle	o Plugged Nozzle	o Decrease Flow	o Fil
o Drinking Water Dispenser (Skylab Design)	o Clogged System o Check Valve Failure	o No Water o No Water Flow Control	o Filt o Pro Repa

FOLDOUT FRAME

RE MODE AND EFFECT ANALYSIS - CLEANSING FIXTURE

DESIGN FEATURE TO PRECLUDE FAILURE	CREW ACTION REQUIRED	SINGLE POINT FAILURE	FAILURE MODE CATEGORY
undant Seals	o Adjust Mechanism & Replace Seals	o No	-
ter Required Upstream	o Filter Maintenance	o No	-
rating Procedures ablished	o Open Poppet per Procedures	o Yes	III
cedures Established for air/Replacement of Unit	o Repair/Replace	o Yes	III
cedures Established for blem Isolation and air/Replacement	o Repair/Replace	o No o Yes	- III
lt-in Safety Factor	o Repair/Replace	o Yes	III
cedures Established for blem Isolation and Repair/ lacement	o Repair/Replace per Procedures if required	o No	-
ually Override to Activate pet	o Manually Override	o No	-
		o No	-
		o No	-
ually Override to Actuate pet	o Manually Override	o No	-
ter Required Upstream	o Remove and Clean	o No	-
ter Required Upstream	o Remove and Clean	o No	-
ter Required Upstream	o Routine Filter Maintenance	o No	-
cedures Established for air/Replacement of Unit	o Repair/Replace per Procedures	o Yes	III

TABLE V-17 FAILURE MODE AND EFFECT ANALYSIS -

OPERATIONAL SYSTEM	FAILURE MODE	RESULT ON SYSTEM	DESIGN FEATURE TO PRECLUDE FAILURE
<u>LIQUID SOAP SYSTEM</u>			
o Soap Storage Bladder Tank	o Increase in Pressure	o Excessive Amount of Soap Dispensed	o Pressure Regulator Must Hav a Relief Valve to Prevent System Overpressure
	o Ruptured Bladder	o Aerated Soap (Suds)	
	o No Pressure on Bladder	o No Soap	
o Solenoid Valve (Fail Closed)	o Power Discontinuity o Foot Switch Malfunction o Component Failure	o Flow Stoppage	o Manually Override to Actuat Poppet
o Solenoid Valve (Fail Open)	o Valve Blockage (Structural or Seal Failure)	o No Fluid Flow Control	o Manually Override to Actuat Poppet
o Soap Nozzle	o Plugged Nozzle	o Decrease Flow	o Filter Required Upstream
<u>DISINFECTANT SYSTEM</u>			
o Disinfectant Stowage Bladder Tank	o Increase in Pressure	o Excessive Amount of Soap Dispensed	o Pressure Regulator Must Hav a Relief Valve to Prevent System Overpressure
	o Ruptured Bladder	o Aerated Mixture	
	o No Pressure	o No Disinfectant	
o Solenoid Valve (Fail Closed)	o Power Discontinuity		o Manually Override to Activat Poppet
	o Foot Switch Malfunction o Valve Stem Damage	o Flow Stoppage	
o Solenoid Valve (Fail Open)	o Valve Blockage (Structural or Seal Failure)	o No Fluid Flow Control	o Manually Override to Activat Poppet
o Disinfectant Nozzle	o Plugged Nozzle	o Decrease Flow	o Removable Unit
<u>PRESSURANT SYSTEM</u>			
o Positive Isolation Disconnect	o Face Seal Leakage	o Loss of Fluid	o Redundant Seals
	o Clogged System	o Reduced Flow	o Filter Required Upstream
	o Poppet Closed	o No Fluid Flow	o Operating Procedures Established
	o Poppet Open	o No Fluid Flow Control	o Procedures Established for Repair/Replacement of Unit

FOLDOUT F

CLEANSING FIXTURE (CONTINUED)

	CREW ACTION REQUIRED	SINGLE POINT FAILURE	FAILURE MODE CATEGORY
e	o Use Bar of Soap	o No	-
		o No	-
		o No	-
e	o Manually Override	o No	-
		o No	-
		o No	-
e	o Manually Override	o Yes/No	III
	o Remove and Clean	o No	-
e	o Manually Apply Disinfectant to Interior Surfaces of Cleaning Fixture	o No	-
		o No	-
		o No	-
e	o Manually Override	o No	-
		o No	-
e	o Manually Override	o No	-
	o Remove and Clean	o No	-
	o Adjust Mechanism and Replace Seals	o No	-
	o Filter Maintenance	o No	-
	o Open Poppet per Procedures	o No	-
	o Repair/Replace	o Yes	-

FOLDOUT FRAME 4

TABLE V-17 FAILURE MODE

OPERATIONAL SYSTEM	FAILURE MODE	RESULT ON SYSTEM	
PRESSURANT SYSTEM (CONTINUED)			
o Pressure Regulator	o Seal Leakage	o No Control of GN_2 Pressure	o Proc Prob Repl
o Isolation Valves (3)	o Seal Leakage	o Undesirable Gas Pressure in Sub-systems	o Proc Prob Repl
AIR DISTRIBUTION SYSTEM			
o Vortex Liquid Gas Separator	o Air Flow Low or Non-existent	o No Liquid-Gas Separation	o Blow befo Can
o Blower	o Power Discontinuity o Output Below Normal o Fan Structural Failure	o Low or No Air Flow	o Proc Prob Repl
o Charcoal Filter	o Clogged Filter	o High ΔP, Low Flow	o Maint
WASTE WATER SYSTEM			
o Maintainable Filter (Liquid)	o Clogged Filter	o High ΔP, Lower Flow	o Maint
o Positive Isolation Disconnect (2)	o Face Seal Leakage	o Loss of Fluid	o Redu
	o Clogged System	o Reduced Flow	o Filte
	o Poppet Closed	o No Fluid Flow	o Opera Estab
	o Poppet Open	o No Fluid Flow Control	o Proce Repai
o Water Pump	o Power Discontinuity	o System Inoperative	o Proce for F Repai
	o Bearing Failure	o System Inoperative	o Beari by So Befor

FOLDOUT FRAME

AND EFFECT ANALYSIS - CLEANSING FIXTURE (CONTINUED)

DESIGN FEATURE TC PRECLUDE FAILUR"	CREW ACTION REQUIRED	SINGLE POINT FAILURE	FAILURE MODE CATEGORY
edures Established for lem Isolation and Repair/ acement	o Repair/Replace per Procedures if Required	o No	-
edures Established for lem Isolation and Repair/ acement	o Repair/Replace per Procedures if required	o No	-
er Must be in Operation re Water Solenoid Valve be Activated	o Verify Blower "on"	o No	III
edures Established for lem Isolation and Repair/ acement	o Repair/Replace per Procedures	o Yes o No o Yes	III - III
ainable Item	o Replace Filter	o No	-
ainable Item	o Replace Filter	o No	-
dant Seals	o Adjust Mechanism and Replace Seals	o No	-
r Required Upstream ting Procedures lished	o Open Poppet per Procedures	o No o Yes	- III
dures Established for r/Replacement of Unit	o Repair/Replace	o Yes	III
dures Established roblem Isolation and r/Replacement	o Repair/Replace per Procedures	o Yes	III
ng Failure Detectable und - Repair/Replace e System Inoperative	o Repair/Replace	o No	-

FOLDOUT FRAME 2

TABLE V-17 FAILURE MODE AND EFFECT ANALYSIS - (

OPERATIONAL SYSTEM	FAILURE MODE	RESULT ON SYSTEM	DESIGN FEATURE TO PRECLUDE FAILURE
o Waste Wate Bladder Tank	o No Pressure on Bladder o Excessive Pressure o Ruptured Bladder	o No Pressurization Transfer o No Control o Gas-Water Mixture in System	o Pressure Regulator Must Have a Relief Valve to Prevent System Overpressure
o Isolation Valves (3)	o Seal Leakage	o Undesirable Fluid in Subsystem	o Procedures Established for Problem Isolation and Repair Replacement
o Positive Isolation Disconnect	o Face Seal Leakage	o Loss of Fluid	o Redundant Seals
	o Clogged System o Poppet Closed	o Reduced Flow o No Fluid Flow	o Filter Required Upstream o Operating Procedures Established
	o Poppet Open	o No Fluid Flow Control	o Procedures Esta .ished for Replacement/Re.air of Unit
o Dome Enclosure	o Insufficient Sealing at Hand Holes and at Dome-Base Interface .	o Fluid Loss Into Environment	o Blower Must be in Operation Before Water Solenoid Valve can be Activated

FOLDOUT FRAME

CLEANSING FIXTURE (CONTINUED)

CREW ACTION REQUIRED	SINGLE POINT FAILURE	FAILURE MODE CATEGORY
o Repair/Replace per Procedures	o No	-
	o No	-
	o No	-
o Repair/Replace per Procedures if Required	o No	-
o Adjust Mechanism and Replace Seals	o No	-
o Filter Maintenance	o No	-
o Open Poppet per Procedures	o Yes	III
o Repair/Replace	o Yes	III
o Verify Blower "On"	o No	-

The failure mode categories identified in the FMEA are defined below:

Category I Failure	-	A single failure which could cause loss of personnel.
Category IIA Failure	-	A single failure whereby the next associated failure could cause loss of personnel.
Category IIB Failure	-	A single failure that could cause return of one or more personnel to to earth, or loss of subsystem function(s) essential to continuation of space operations and scientific investigation.
Category III Failure	-	A single failure which could not result in loss of primary or secondary mission objectives or adversely affect crew safety.

There are no Category I and II failure modes on the cleansing fixture.

4. Logistic Support - Until reliability numbers are derived for individual components, the following items are likely to require logistic action:

- Towel supply
- Filter cartridges
- Fluorescent light bulb
- Water pump
- Seals for positive isolation disconnect (PID)
- Liquid soap
- Disinfectant
- Bar soap
- Types and quantities of chemical waste dictate charcoal replacement

The liquid soap and disinfectant storage tanks are sized for a 30-day mission and will require refilling at the end of the 30-day period. Bar soap shall be provided as a redundant cleanser in case of liquid soap dispensing failure.

5. Enclosure Cleaning - Removing water droplets from the interior surface of the enclosure can be accomplished by one of the following methods:

- o User's hands
- o Hand held scraper
- o Mechanism incorporated into enclosure

The most convenient method of cleaning the enclosure is by the crewman funneling the water droplets to the apex of the enclosure base with his hands. This operation may be objectionable by some, whereby a hand held scraper that conforms to the interior curvature could be utilized. A more elaborate method would be a scraper device that is an integral part of the enclosure which consists of wiper members that are operated externally to the enclosure. All methods perform this task satisfactorily, so the method recommended depends on the attitude of the crewmen who are to use the unit.

VI. CONCLUSION AND SUMMARY

The conclusions resulting from the individual task efforts are described in the following paragraphs.

A. TASK 1 - SELECTION OF UTENSIL/HAND CLEANSING FIXTURE CONCEPT

Cleansing Fixture concept number one as presented in Section III.F. is selected as the optimum based upon limited feasibility testing and comparative tradeoff analysis. This concept utilizes a low air purge and requires the crewman to assist in cleanup after usage. This concept has the least impact on the spacecraft systems and incorporates the selected spacecraft subsystems resulting from the tradeoff analysis. The primary subsystems are as follows:

- Enclosure Configuration: Hemisphere dome with shallow cone base
- Water Limiting Device: Flow nozzle (hollow cone) with isolating valve
- Water Collection: Low air purge
- Liquid-gas Separator: Vortex

The automatic mode of operation for the fixture is possible and has been incorporated in the concept for handwashings only, however, the efficiency of utilizing the fixture in this mode is questionable. The first detriment to automatic mode of operation is the length of time required to accomplish the task. For each step function, the timing sequence must be set for the maximum time so that all crewmen could accomplish their handwashings completely. This requires the maximum power and impact on the spacecraft. If individual time sequences were programmed into the electrical circuitry for each subtask (i.e., rinsing), the operation of the fixture would be complicated for the crewman as well as having more hardware adding to weight, power and reliability.

The second detriment to automatic operation is that the crewman must interface with the fixture for cleanup operations. If automatic cleanup was incorporated into the design concept, the air flow rate must be increased to attain a uniform 10.1 m/s (33 fps) minimum flow throughout the enclosure to move the water droplets toward the water collection system. In addition, an air heater must be incorporated for crewman comfort. This concept would reflect the weight and penalty assessment allocated to cleansing fixture concept number 5 which is extremely high.

The third detriment toward automatic operation involves the use of the fixture for other tasks besides handwashings. The utensil washing task would require a crewman to manually accomplish the washing. Otherwise, automatic equipment such as multi-nozzles that allow for various sprays to accomplish wetting, rinsing and cleanup operations would have to be incorporated. This would add to the volume, weight and power requirements.

B. TASK 2 - FEASIBILITY TESTING

1. Cleansing Tasks - The following table summarizes the average totals for soap, water and time used to perform the task listed.

TABLE VI-1 FEASIBILITY TEST RESULTS

CLEANSING TASK	SOAP (ml)	WATER (ml)	TIME (SECONDS)
Handwashing	1.5	181	71.1
Utensil Cleansing	1.6	111.7	58.8
Shaving	4.65	679	266.7
Brushing Teeth	-	187	142.4
Hair Wetting	-	68.8	88
Body Wash	-	250	-
Clothes Wash (T-Shirt)	22.5	1387	268.5

For the performance of all test tasks, the test subjects were asked to fill out a questionnaire. Comments made by a majority of the test subjects in favor of the present design include:

- o Comfortable to use
- o Good ease and comfort of obtaining water and soap

- Air flow within the enclosure was comfortable
- Hand holes were comfortable
- Foot operated on-off switch preferred to knee, hand or forearm
- Water and air temperature comfortable
- The enclosure shape was adequate for maneuverability

Many subjects commented that the enclosure height needed to be changed and that possible angling of the entire fixture would be beneficial in both visibility and ease of doing the task. However, it must be remembered that these feasibility tests were done in a one "g" environment and that the human body tends to form in a fetal position in a zero "g" environment, thus conforming more to the present design of the enclosure. Aside from these two comments, the Utensil/Handwashing fixture appears to be highly satisfactory as far as ease and comfort of performing a given task.

When washing the clothes, fogging of the enclosure due to the article blocking air flow through the enclosure caused very poor visibility. Test subjects commented that due to this fact they could not tell when enough soap had been applied and when the article was clean. The bulkiness of the T-shirt made maneuverability within the enclosure to clean a particular part of the clothing nearly impossible. It was, therefore, concluded that due to the excessive time involved, water usage, soap usage and discomfort, that apparel washing in the present design of the cleansing fixture was infeasible. All other tasks were considered feasible to be accomplished in the cleansing fixture.

2. Microbial Control - A disinfectant test was performed to determine the effectiveness of different substances in reducing the population of "*E. coli*" microorganisms in 40 minutes. The percent reduction was as follows:

- Olive Leaf: 93.3%
- Wescodyne: 100%
- Sodium Meta-bisulfite: 100%

3. <u>Waste Fluid Dumping</u> - Testing was performed on chemical dumping into the fixture. For the purpose of this test only those "waste chemicals" compatible with a Plexiglas liquid/gas separator could be used. In addition, only those materials already on hand were used. Four materials were tested:

Ethyl Alcohol
Dioxane
Trichloroethane
5% Acetic Acid

To conduct the test, 20 ml of the material was dumped into the bottom of the fixture with the blower on at 26.5 m^3/sec (15.58 CFM). The time was recorded from the dump until the last drop fell into the graduated cylinder at the bottom of the sump. Table VI-2 shows the test data.

TABLE VI-2 MATERIAL COMPARISON

Material	Time (Sec)	m^3 (Cu Ft) Air	ml Collected	ml Vaporized	g Vaporized
Ethyl Alcohol	65	.48 (16.9)	10.2	9.8	7.735
Dioxane	55	.40 (14.3)	14.0	6.0	6.2
Trichloroethane	37	.27 (9.6)	12.5	7.5	10.824
5% Acetic Acid	40	.29 (10.4)	15.8	4.2	4.2

C. TASK 3 - REQUIREMENTS DEFINITION

1. <u>Selected System</u> - The configuration of the selected system is shown in Figure V-5 with a crewman interfacing with the unit. The mechanical schematic of the selected system is shown in Figure V-3 and the electrical wiring diagram in Figure V-4. The equipment layout is shown in Figure V-7.

Removing water droplets from the interior surface of the enclosure can be accomplished by one of the following methods:

- o User's hands
- o Hand held scraper
- o Mechanism incorporated into enclosure

The most convenient method of cleaning the enclosure is by the crewman funneling the water droplets to the apex of the enclosure base with his hands. This operation may be objectionable by some, whereby a hand held scraper that conforms to the interior curvature could be utilized. A more elaborate method would be a scraper device that is an integral part of the enclosure which consists of wiper members that are operated externally to the enclosure. All methods perform this task satisfactorily, so the method recommended depends on the attitude of crewmen that are to use the unit.

2. Projected Size and Weight - The system was designed to fit within the standard lab experiment rack or be installed as an individually floor mounted equipment module. Width of the unit is 571.5 mm (22.5 inches) with a height of 1770.4 mm (69.7 inches) and with a depth that varies from 546.1 mm (21.5 inches) to 759.5 mm (29.9 inches).

The system equipment weight made up of water, disinfectant, waste water, air movement, nitrogen pressurization, drinking water and electrical subsystems plus the structural hardware is 52.1 kg (114.82 pounds). The equivalent weight impact for (5) and (10) handwashings per day is shown in Tables V-11 and V-12, and a graph illustrating additive tasks with associated increase in equivalent weight penalty is shown in Figure V-2. Total weight including equipment and weight penalties are 386 kg (844 pounds) for (10) handwashings and 292 kg (640 pounds) for (5) handwashings per day.

3. Charcoal Requirements - Assuming all the preliminary selected chemicals are dumped once per day and that the .42 m^3 (15 ft^3) of purged air saturated with the chemical vapors, the total weight of vaporized chemicals is 3.04 kg (6.72 lbs). For a 30 day mission, the total weight becomes 91.3 kg (201.6 lbs).

Since charcoal is assumed to absorb 20% of its weight in chemical vapors, the theoretical charcoal weight becomes:

$$\frac{3.04\ \text{kg}}{.20} = 15.2\ \text{kg (33.6 lbs) per day}$$

$$\frac{91.3\ \text{kg}}{.20} = 456.7\ \text{kg (1008 lbs) for 30 days}$$

Based on experimental dumping of chemical fluids in the feasibility handwashing fixture, the weight of chemical vapor is 17.5 percent by weight of the theoretical values. Therefore, the following values should be used for the charcoal weight requirement:

(.175)(15.2 kg) = 2.7 kg (5.88 lbs) per day

(.175)(456.7 kg) = 79.9 kg (176.4 lbs) for 30 days

Recommendations

a. Better guidelines are needed as to what type and quantity of various waste chemicals would be generated in the spacelab.

b. Using mainly solvent type materials for examples of waste chemicals to be disposed of in spacelab is potentially misleading and could result in inadequate planning for actual missions. There are a vast multitude of possible waste material that could be generated, some easier and some harder to dispose of than the ones listed.

c. A possible alternative solution would be to use a waste chemical disposal unit designed for zero-g laboratory use.

4. Possible Applications - The following are areas that would benefit from the use of a utensil/hand cleansing fixture:

- o Space experiment modules (Shuttle payload area)
- o Shuttle galley
- o Long duration space missions

D. TASK 4 - DOCUMENTATION

This task prepared the documentation and reports required by the data requirements list (DRL) number T-1097. These included the following:

- o Monthly Progress Reports (MCR-75-257)
- o Final Report (MCR-75-486)
- o Development Plan (MCR-75-216)
- o Requirements Definition Document (MCR-75-474)

- Tradeoff Analysis Report (MCR-75-347)
- Test Report (MCR-75-433)
- Test Plan (MCR-75-271)
- Design Requirements Document, WBS 1115 (MCR-75-217)

E. PROPOSED WORK

The concept feasibility study for a spacecraft utensil/hand cleansing fixture was conducted with limited testing to determine parameters associated with the fixture design. This study has shown that a zero gravity cleansing fixture is feasible. During the course of this concept study, design development needs were identified and a preliminary design was established to a top-level detail.

The recommended future Spacecraft Utensil/Hand Cleansing Fixture program plan is to develop a preliminary design into a working breadboard system that can be tested and evaluated. Based on the breadboard evaluations, a prototype unit could then be designed and fabricated. This unit could then be evaluated through a series of tests consisting of both one gravity and zero gravity environments. Based on the results of this program, a flight article specification could be defined and prepared. The design shall be compatible with Shuttle and Spacelab configuration layouts and shall have minimum impact c the spacecraft and its associated systems. This effort is divided in tasks over a 24-month duration from authority to proceed and is outlined below:

1. <u>Task 1 - Breadboard Design and Fabrication</u> - The contractor shall design and fabricate breadboard-type hardware that can be utilized to evaluate the cleansing fixture in a series of tests consisting of one gravity, neutral buoyancy, and KC-135 aircraft simulating zero gravity. The design and fabrication shall be from materials suitable for testing to meet the requirements stated in Paragraph III.A.2 and III.A.3.

2. Task 2 - Breadboard Testing - The breadboard hardware shall be tested to provide performance and functional data that can be utilized to design a prototype cleansing fixture. The testing shall develop quantitative criteria that can be utilized to assess the impact on the spacecraft systems. The following tests will be conducted to obtain the stated objectives:

a. One-g Laboratory Tests - The objective of these tests is to establish criteria for the following as a minimum:

1) Set up test to dump chemical fluids (refer to MCR-75-347, Section IV-B4) into the fixture and determine what chemical reactions take place and what gases are evolved.

2) Determine effective spray location and pattern for automatic disinfecting of fixture.

3) Perform microbiological tests for 70 day handwashings.

4) Test effectiveness of bacteria on charcoal filter in removing particles from the blower air.

b. Neutral Buoyancy Tests - The objective of these tests is to determine man-machine interfacing criteria in a simulated weightless environment for the following as a minimum:

1) Verify or re-evaluate man-machine interfacing with enclosure design (Hand holes).

2) Investigate switch activation and restraint technique (foot, hand, or knee activated).

3) Determine effects on cabinet design of zero-g posture.

4) Investigate miscellaneous restraints for equipment associated with the fixture (towels, sponge, utensils).

5) Verify one-g man-machine fixture interfacing.

c. KC-135 Tests - The objective of these tests is to determine the feasibility of performing the following tasks and evaluating techniques to establish design criteria:

1) Perform test on the feasibility of either removing whiskers from direct water stream, or in a basin full of water.

2) Perform test to verify the effectiveness of the water collection system.

3) Develop effective means of dumping liquids into the fixture in zero-g.

4) Develop a wipe-down mechanism to collect water from the inside surface of the fixture and verify its effectiveness.

5) Find effective water spray pattern for utensil cleansing.

6) Verify neutral buoyancy and one-g man-machine fixture interfacing.

3. <u>Task 3 - Preliminary System Specification</u> - The contractor shall prepare a preliminary system specification based on the results of Task 2 testing. The purpose of this preliminary system specification is to define a baseline for the design of a prototype cleansing fixture. This specification shall include system requirements, interfaces, operational aspects, overall design, and any other applicable technical characteristics. The specification shall be in sufficient detail to comprehensively explain all the technical requirements and features of the total system.

4. <u>Task 4 - Prototype Cleansing Fixture Design</u> - The contractor shall develop the design and prepare detailed and assembly drawings/specifications which shall include all the technical design requirements, characteristics, and features of the equipment comprising the system. The specifications shall be in sufficient detail that the equipment can be fabricated, assembled, and operated. The drawings/specifications shall include a list of all the parts and components utilized. The list shall be properly identified, including the manufacturer's name and any other pertinent information. NASA-JSC shall approve the design.

5. <u>Task 5 - Prototype Cleansing Fixture Fabrication</u> - The contractor shall fabricate a prototype cleansing fixture in accordance with the NASA approved drawing/specifications in Task 4. The fixture shall be inspected after fabrication to ensure that the unit is in accordance with the design drawings/specifications.

6. <u>Task 6 - Prototype Cleansing Fixture Performance Tests</u> - The contractor shall test the fixture to demonstrate that all functions and features are satisfactory for nominal conditions in both a one gravity and a weightless environment. Off-design conditions shall be imposed to define limitations and possible failure modes. The test data shall be analyzed to determine potential design improvements to extend the performance limits. The following test requirements are considered minimum and general, therefore, the contractor is encouraged to add to and modify the requirements as necessary to enhance the program:

a. Water distribution system suitability;

b. Soap distribution system suitability;

c. Water collection system suitability;

d. Air distribution system suitability;

e. Task performance capability for washing hands, washing utensils, shaving, brushing teeth, whole body sponge-bath, oral hygiene, and washing of hair;

f. Cabinet man-machine interfacing suitability including restraint system;

g. Maintainability aspects of hardware design.

Test data shall be obtained and recorded to fully assess the impact on the spacecraft systems. A test report shall be prepared to record the data including photographs.

7. <u>Task 7 - Preliminary Flight Article Specification</u> - The contractor shall prepare a preliminary flight article specification that defines system requirements, interfaces, operational aspects, overall design, and recommended testing. The specification shall be based on the results of the previous six tasks and shall be in sufficient detail to comprehensively explain all the technical requirements and features of the total system.